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COLLEGE STATION, TEXAS
OCT 17 1960

Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

PRICE 2/6 OCTOBER 1960

Vive le new Power Alliance!
Contracts for the manufacture and laying of the cross-Channel submarine power link have now been placed by the Central Electricity Generating Board and Electricité de France.
'Ooray for British Cable!
The British contribution to the cross-Channel submarine cable is a joint enterprise—by AEI Cable Division in association with BICC.

Two single-core submarine power cables, carrying the heaviest d.c. load ever transmitted by a single circuit under water, will link England and France.

AEI **CABLE DIVISION**

Associated Electrical Industries Limited

51-53 Hatton Garden, London EC1. *Phone CHAncery 6822*

Research for Perfection

The Reyrolle Research Station used for the short-circuit proving and development-testing of their switchgear

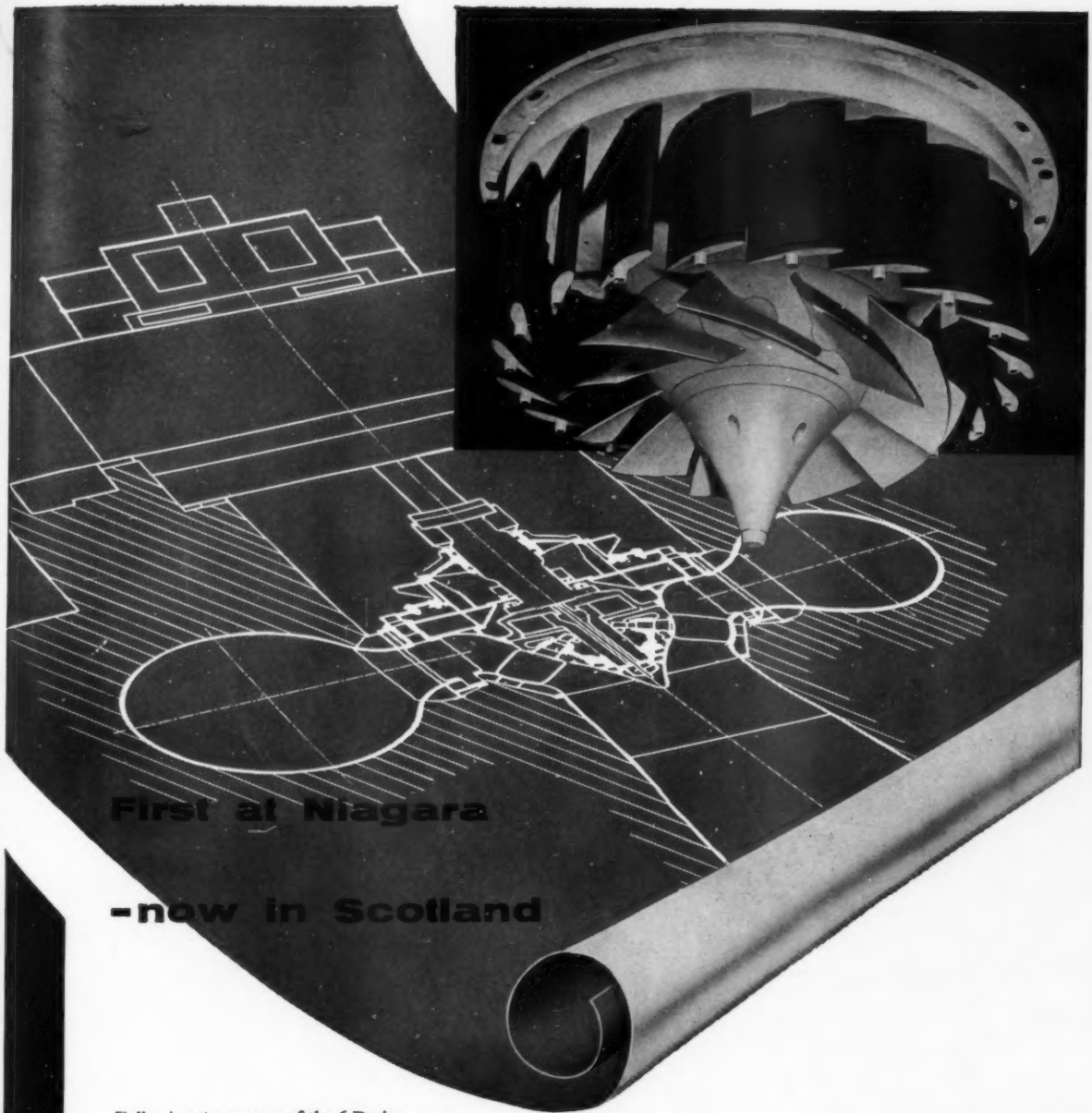
All Reyrolle products are backed by highly organised research and development facilities to ensure the excellence of performance for which they are noted

Specialists in the manufacture of :

AIR-BLAST SWITCHGEAR
SMALL-OIL-VOLUME SWITCHGEAR
METALCLAD SWITCHGEAR
AIR-BREAK SWITCHGEAR
FLAMEPROOF SWITCHGEAR
DISTRIBUTION SWITCHGEAR
CONTROL EQUIPMENT
PROTECTIVE GEAR
ARC-WELDING EQUIPMENT
A.C. COMMUTATOR MOTORS
ELECTRICAL ACCESSORIES

Reyrolle

A. REYROLLE & CO. LTD - HEBBURN - COUNTY DURHAM - ENGLAND



Following the success of the 6 Deriaz reversible pump turbines at Niagara, a 30,500 h.p., 180 feet head Deriaz turbine coupled to a 22 MW alternator has been ordered for the Culligran Power Station of the North of Scotland Hydro-Electric Board. A maximum efficiency of 91·7% was obtained on a 20-inch diameter model. This will be majorated as usual for the full-sized turbine.

'ENGLISH ELECTRIC'

hydro-electric equipment

THE ENGLISH ELECTRIC COMPANY LIMITED, MARCONI HOUSE, STRAND, LONDON, W.C.2
Hydro-Electric Department, Dunnings Bridge Road, Netherton, Bootle, 10
WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON HE.38

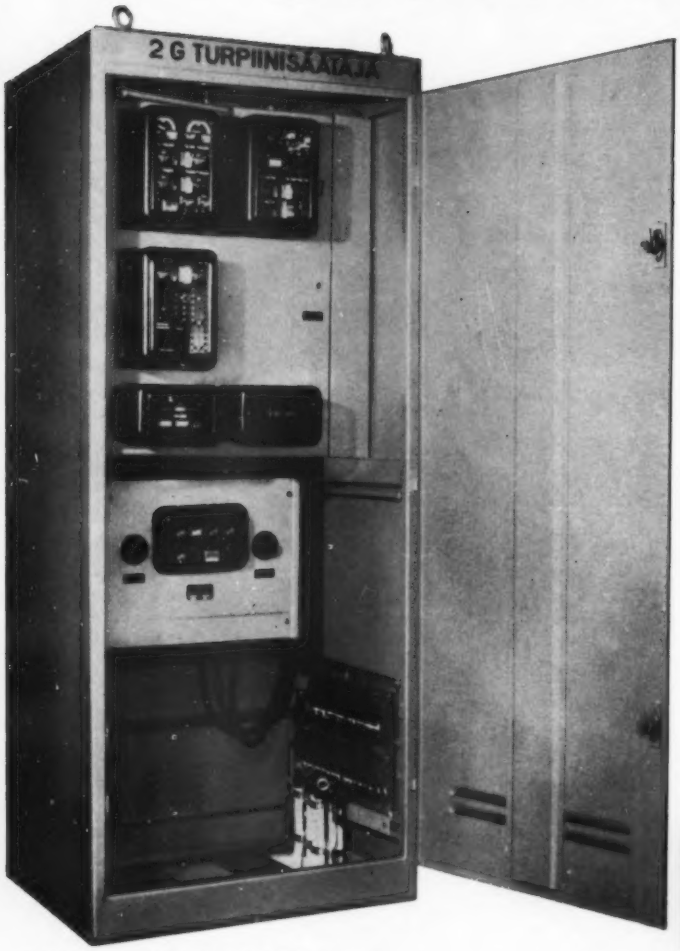
ASEA Electro-hydraulic Governors

are controlling today 8,5 million horse power

Since the first ASEA governor of commercial design went into operation in 1944, ASEA has delivered, or has now on order, governors for a total turbine output of more than

11,000,000 h. p.

Among these are also governors for steam and gas turbines.



Cubicle for an ASEA electro-hydraulic governor for a 200,000 h.p. Francis turbine.

Reference list

Country	Number of governors	Turbine output h.p.
Australia	6	385,000
Austria	6	263,000
Brazil	4	800,000
Canada	9	380,000
China	1	11,000
Finland	15	660,000
France	4	240,000
India	1	57,000
Japan	17	1,230,000
Norway	9	560,000
Sovjet Union	5	96,000
Spain	2	37,000
Sweden	100	6,320,000
Venezuela	2	27,000
Yugoslavia	2	72,000
Total in April 1960	183	11,138,000

To the right
Interior view of the Swedish power-station Stornorrfors with three 150,000 kVA ASEA generators. The turbines are equipped with ASEA electro-hydraulic governors.

To the left
Complete electro-hydraulic governor delivered by ASEA in 1948.

Boving design and finish ensure ENDURING EFFICIENCY

This solid cast stainless steel runner for Scotland illustrates the high quality of finish to very fine limits which is a feature of Boving turbine runners of all types.

Constant research into design and production methods, backed by the latest advances in technology, maintain Boving Quality at the highest standard. High quality finish ensures high efficiency, increases reliability, and reduces costly outages.

Boving
& CO. LIMITED

VILLIERS HOUSE 41-47 STRAND LONDON WC2

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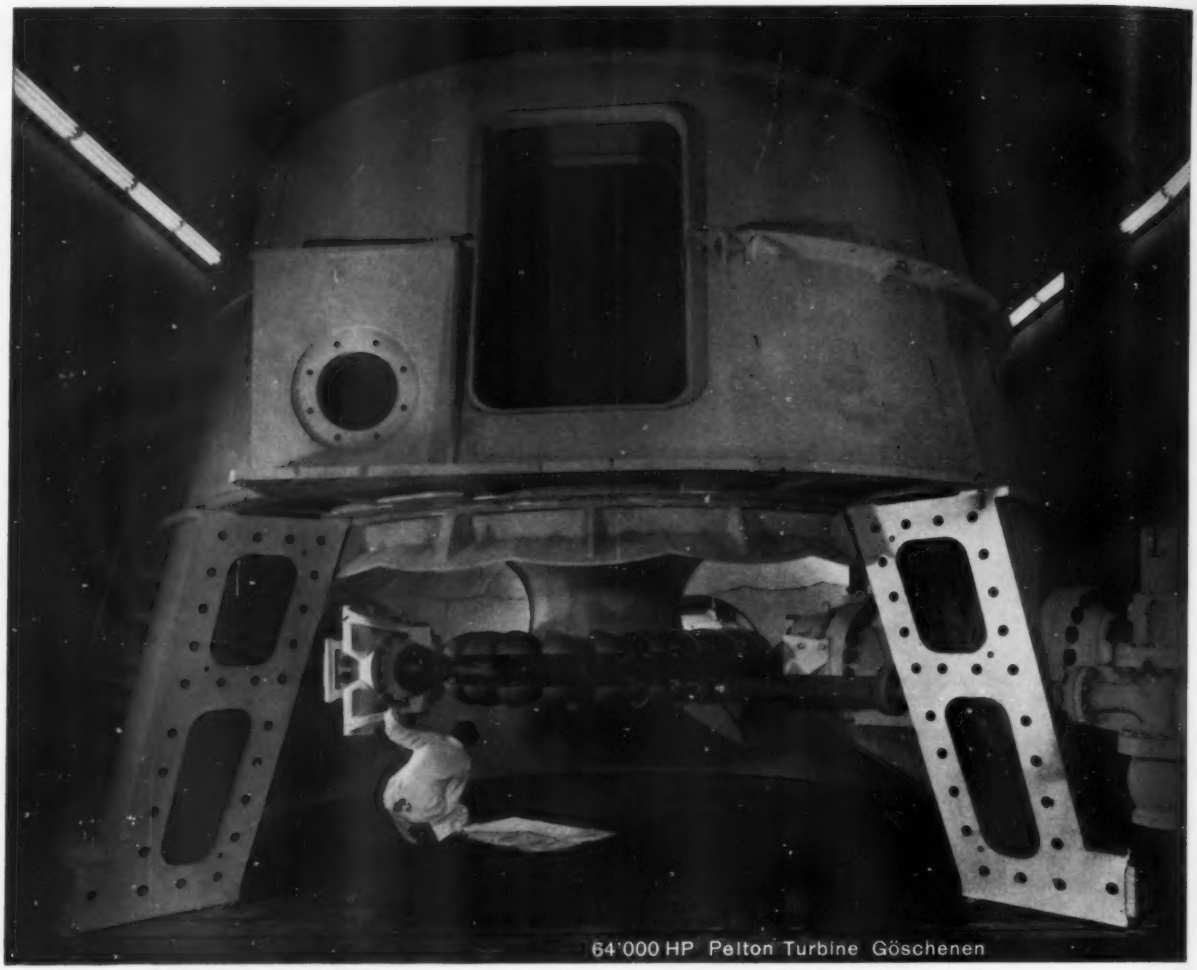

64'000 HP Pelton Turbine Göschenen

TRADITIONAL SWISS ENGINEERING SKILL AND QUALITY

A century of experience in design and construction of waterpower-equipment and constant research in two hydraulic laboratories, one of them especially equipped for cavitation tests, assure the reliablity and efficiency for which Bell turbines are renowned

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Bell builds:
Water Turbines, Spherical straight flow valves, Butterfly valves, Penstocks and supply pipings, Pressure tunnel liners, Partially or fully automatic and remote controlled plants, Power house cranes, Towers for transmission lines, Water control equipment

Some projects with Bell Equipment:
Francis Turbines - Guyabo (El Salvador) head 56 m, 24'800 HP - Bärenburg (Switzerland) head 340 m, 85'000 HP (Supply together with Charmilles)
Pelton Turbines - Göschenen (Switzerland) head 698 m, 64'000 HP - Sedrun (Switzerland) head 588 m, 70'000 HP
Kaplan Turbines - Wildegg Brugg (Switzerland) head 15,3 m 34'000 HP - Petäjäskoski (Finnland) head 19 m, 67'600 HP

Bell Engineering Works Ltd.
Kriens/Lucerne (Switzerland)

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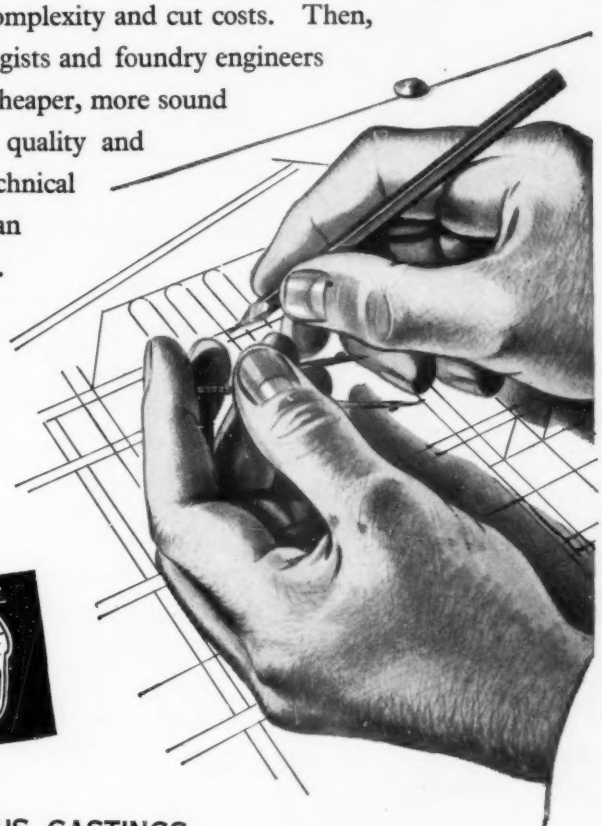
re-designing?

Start right at the beginning. Ask our design engineers to reconsider the basic form of your castings. Very often they can improve the structural form, and at the same time reduce complexity and cut costs. Then, when our metallurgists and foundry engineers take over, you'll be getting cheaper, more sound castings of unequalled quality and accuracy. This is what we call technical teamwork and we're proud of it. It can tackle *all* your casting problems and *solve* them.

CASTINGS FROM A FEW OUNCES TO 10 TONS

in phosphor-bronze, gun-metal, aluminium-bronze, manganese-bronze, and light alloys. Precision machined bushes and bearings. Specialists in high-tensile aluminium-bronze castings, centrifugal-cast wheel blanks, shell moulded castings, and chill-cast rods and tubes. Continuous cast phosphor-bronze bars up to 12 foot lengths.



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HIGH-DUTY IRON CASTINGS · PRECISION MACHINED BUSHES & BEARINGS

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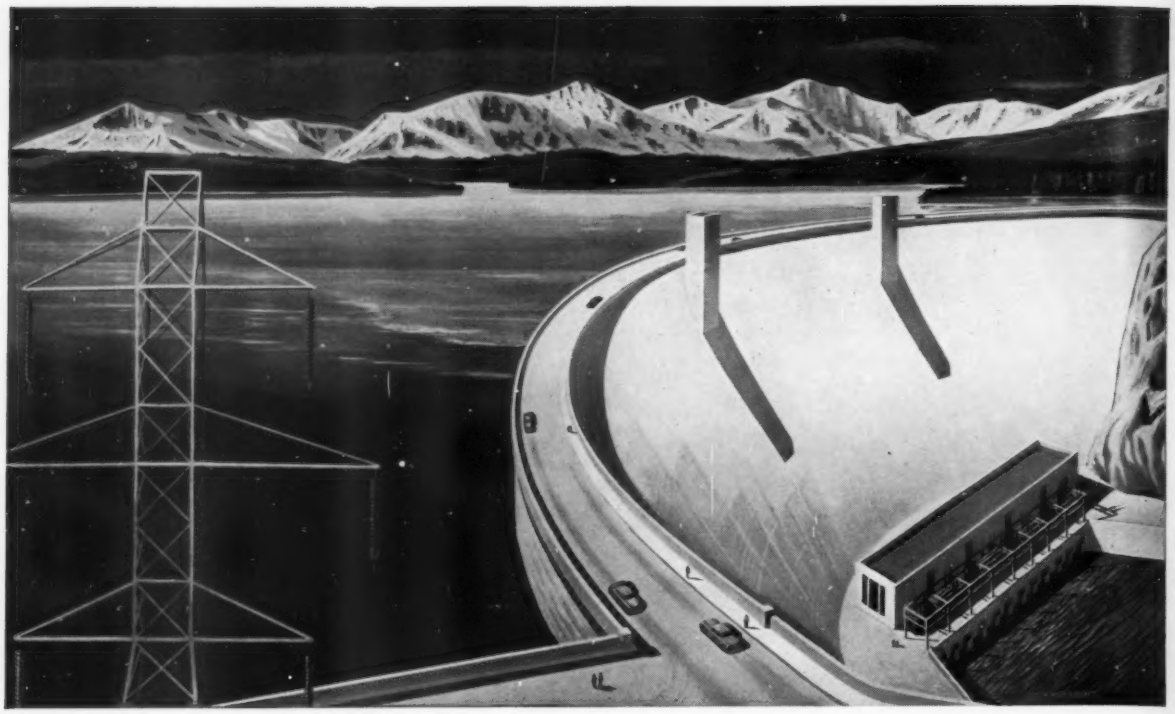

KULJIAN . . . SPECIALISTS IN POWER

4,000,000 KILOWATTS . . . that's the total generating capacity represented by the more than 100 Kuljian power projects now in operation throughout the world. Kuljian engineers are specialists in power—qualified by experience to design, engineer and supervise construction of hydroelectric, steam, internal combustion and nuclear power plants and associated facilities.

Every Kuljian hydroelectric project combines the skills and experience of a complete staff of internationally recognized experts in all phases of water resources development. No matter what your next power project might be, The Kuljian Corporation is fully prepared to undertake efficiently all phases of design, engineering, and construction supervision to help bring about the quick, economical solution to your specific problem.

- Surveys
- Investigations
- Reports
- Reservoirs and Dams
- Hydroelectric Power Stations
- Transmission and Distribution Sub Stations
- Pumping and Filtration Plants
- Tunnels and Aqueducts
- Irrigation and Flood Control
- Other Reclamation Activities

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engineers • constructors

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HYDROELECTRIC DIVISION

1006

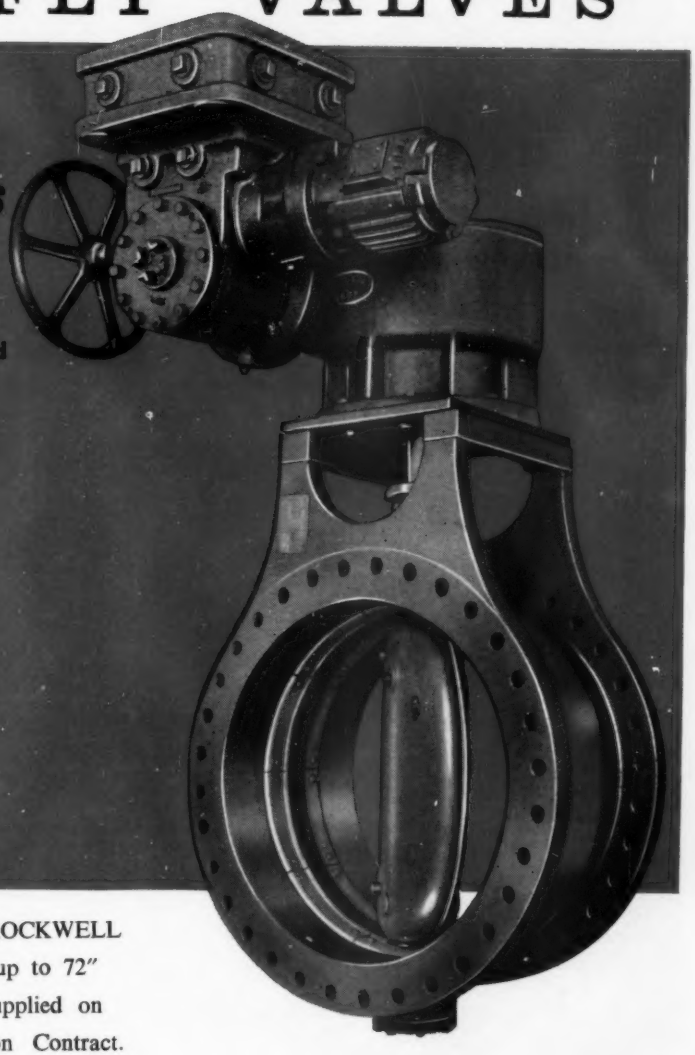
DESIGN • ENGINEERING • PROCUREMENT • CONSTRUCTION • REPORTS

From Pakistan, to Greece or anywhere in the world

COCKBURN-ROCKWELL
BUTTERFLY VALVES

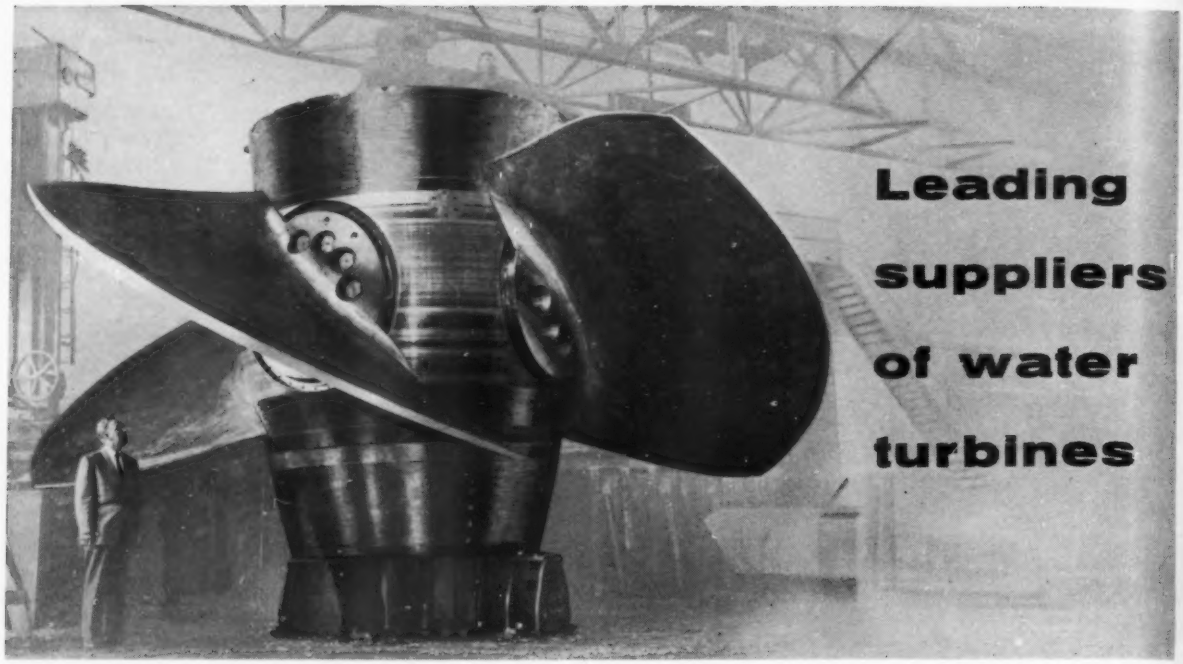
offer a BIG list of advantages

- ★ Leak-tight shut off.
- ★ Great economy in space, compared with gate or globe valves. 2/3 of weight approx.
- ★ No fouling, low pressure drop.
- ★ Easy operation.
- ★ Simple, solid design of body, disc and shaft. Great strength, minimum maintenance.
- ★ International servicing available.



Thirty-six COCKBURN-ROCKWELL Butterfly Valves in sizes up to 72″ diameter were recently supplied on a Pakistan Power Station Contract. A further thirty valves, 48″ to 72″ diameter, are now being installed in the Athens Water System extension.

COCKBURNS LTD Cardonald Glasgow SW1



Runner for The Baygorria Power Station, manufactured in NOHAB's shops.

Below is a table of important orders for NOHAB turbines.

Power Station	Number and type of turbine	Head		Output Metric HP per turbine	Speed r.p.m.	Comments
		ft.	m.			
STORNORRFORS Sweden	3 Francis	246-0	75-0	200,000	125	The most powerful water turbines in Europe.
LASELE Sweden	2 Kaplan	170-6	52-0	87,200	150	This is the highest head for which a Kaplan turbine has been installed in Sweden.
PORSI Sweden	2 Kaplan	118-0	33-0	120,200	115	These will be the most powerful Kaplan turbines in Sweden.
MAEL Norway	1 Francis	147-6	45-0	51,000	150	With regard to dimensions, the largest turbine in Norway.
PANCHET HILL India	1 Kaplan	113-0	34-4	80,000	125	India's largest Kaplan turbine in output as well as dimensions.
RINCON DE BAYGORRIA Uruguay	3 Kaplan	48-2	14-7	49,500	79	With regard to dimensions, South America's largest turbines.
FURNAS Brazil	4 Francis	308-4	94-0	230,000	150	Among the world's most powerful turbines

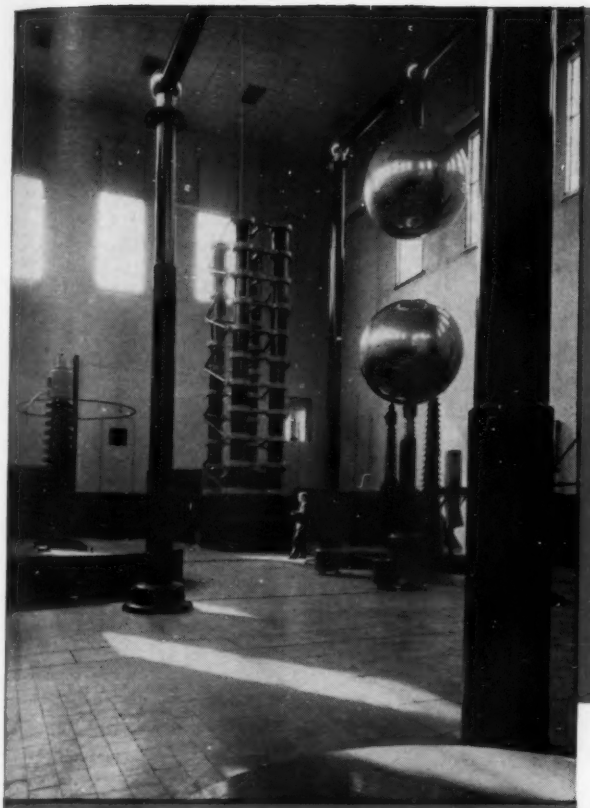
NOHAB

Ample supply of energy in convenient forms is a fundamental condition for the standards of living. NOHAB turbines help to produce electric power in water power plants all over the world.

NYDQVIST & HOLM AKTIEBOLAG, TROLLHÄTTAN, SWEDEN

Cables: NOHAB Phone: 18000 Telex: 5284

Subsidiary in Canada: Nohab Canada Ltd.
Montreal. 1410, Stanley St., Montreal, Quebec. Phone: VIctor 9 14 85 or 60
Toronto. North Line Road, Toronto, Ontario. Phone: OXford 9 01 00
} Cables Nohabcan

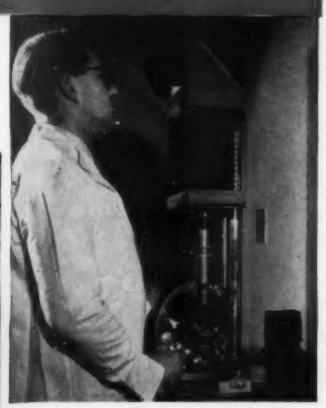


Good Electrical Insulation is synonymous with Good Electrical Equipment

Leading manufacturers use M & I electrical insulating materials because our facilities ensure that all our products are manufactured to the highest standards.

2,500 kV Surge Generator Equipment— E.H.V. Test Building.

BELOW. Water-absorption meter— Chemical Laboratory.



ABOVE. Using a Photomicroscope— Research Laboratory.

BELOW. Tabulating thermal characteristics. Insulating materials being placed in high temperature oven— Development Laboratory.

Products :—

MICA: block, splittings and fabricated parts.
MICANITE: built-up mica insulation of every type in the form of sheets, tubes, cylinders, V-rings, covered bars.
"SAMICA" the new brand of mica paper insulation—supplied under exclusive licence in Great Britain, Northern Ireland, Eire and most of the British commonwealth.
PAXOLIN: synthetic resin bonded laminates having paper, fabric, glass, nylon, asbestos or other fillers are bonded with ethoxyline, melamine, phenolic, silicone or other resins to produce various grades for punching, moulding or machining.
SILICONE INSULATION: a range of materials for Class H applications, silicone glass fabric, silicone bonded glass laminates, silicone bonded Micanite sheets, tubes, V-rings, etc., silicone glass mica tapes; silicone combination insulation and silicone elastomer tapes.
EMPIRE VARNISHED INSULATION: paper, cotton, silk, Terylene, nylon and glass in the form of sheets and tapes treated with various impregnants including ethoxyline.
COPPER FACED PAXOLIN.
HIGH VOLTAGE BUSHINGS & INSULATORS: for all voltage ratings and for indoor and outdoor equipment.
TRANSFORMER CYLINDERS.
PANILAX: (aniline-formaldehyde) resin mouldings.
Distributors of :—
VULCANISED FIBRE: sheets, tubes, rods and fabricated parts.
LEATHEROID: sheets, rolls and punched parts.
MICOFLEX (PVC): polythene and other thermoplastic extrusions and injection mouldings.

m and i the electrical insulation people

THE MICANITE & INSULATORS CO., LTD.,

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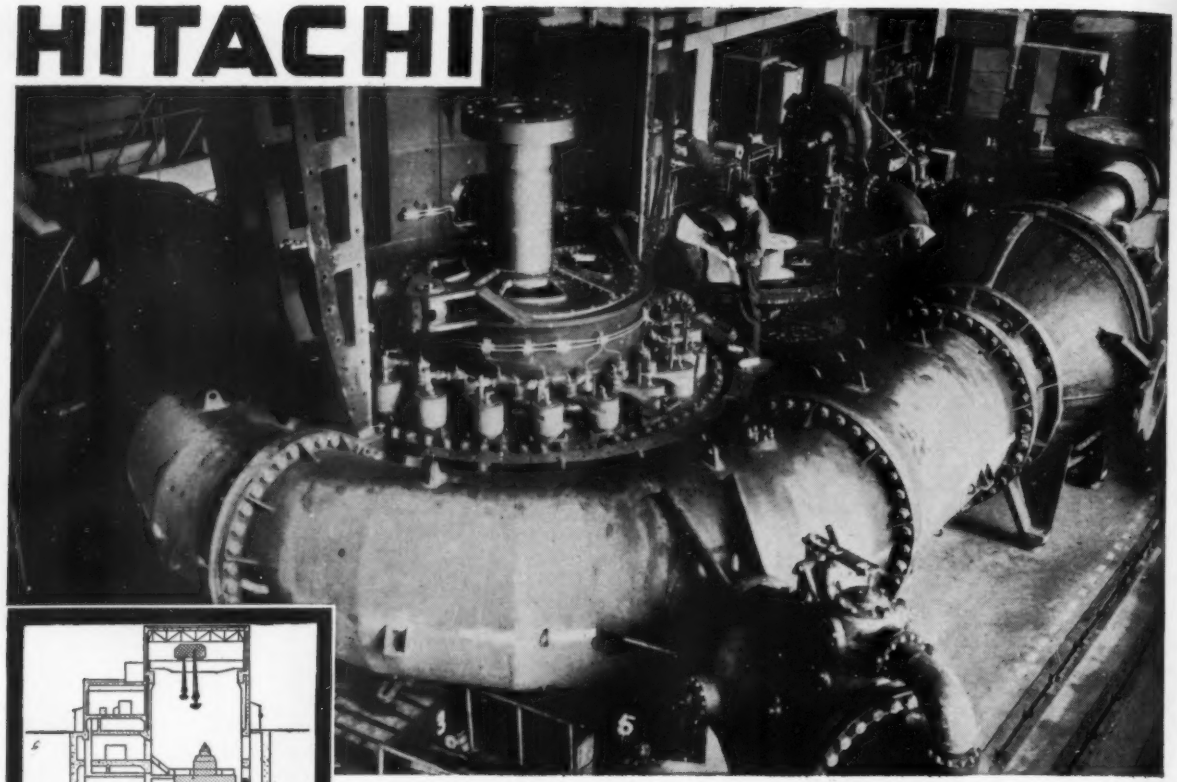
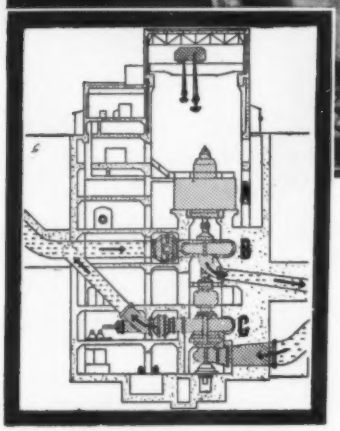
"SAMICA", "PAXOLIN" and "PANILAX" are our registered trade marks *"Terylene" is a registered trade mark of I.C.I.*

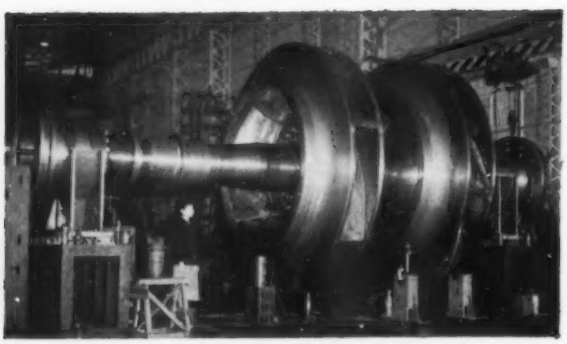
HITACHI





A Generator-Motor
B Turbine
C Pump

▼ Pump Impeller



Pump and Turbine Completed for the Huge Pumped Storage Power Station

Hitachi, Ltd. has recently completed a mammoth vertical shaft 56,500 kW turbine pump for delivery to the Morozuka Pumped Storage Power Station in Japan to surpass world level in this field. This turbine pump is scheduled to be installed with a 58,000 kVA/56,500 kW generator-motor and a 53,000 kW turbine, also of the Hitachi make.

This pump is to be operated on surplus power when it becomes available on such occasions as rainy seasons or midnight operations for pumping up water to the reservoir. The water stored this way is used to increase power output of the station in the peak-load period.

Hitachi, Ltd.
Tokyo Japan
Cable Address: "HITACHY" TOKYO

The Specifications of the various parts are as follows:

Pump	Quantity	18.6 m³/s
	Total Head	241.4 m
	Speed	300 rpm
Turbine	Effective Head	222 m
	Output	53,000 kW
	Speed	300 rpm

Generator-Motor	Output	58,000 kVA (Generator)
		56,500 kW (Motor)
	Voltage	11,000 V
	Current	3,045 A
	Frequency	60 cycles
	Speed	300 rpm

Beside the above, Hitachi, Ltd. also made and delivered automatic operational control equipment, transformers, switchboards, A.C. circuit breakers, overhead travelling cranes and other equipment for the Morozuka Power Station.

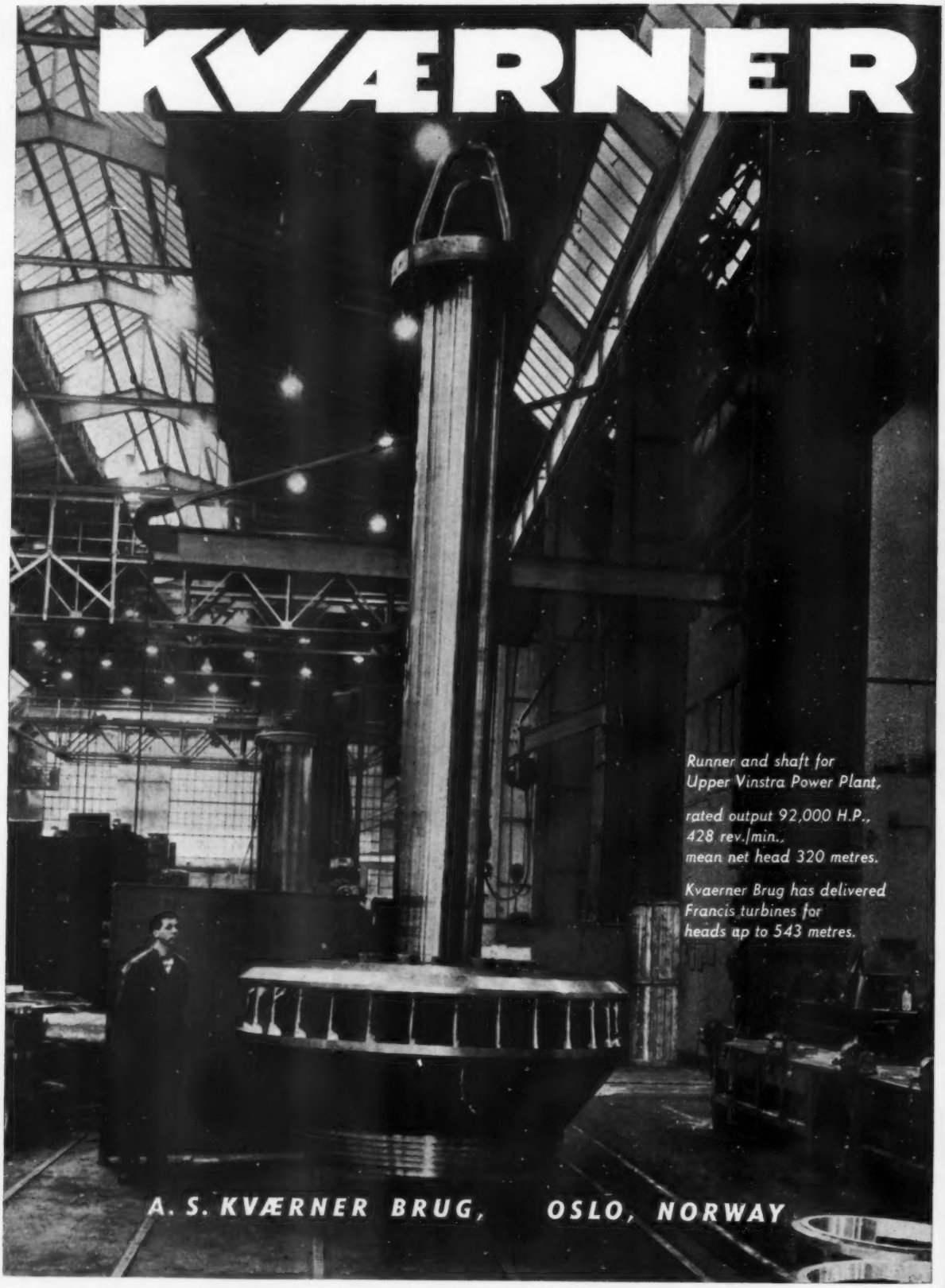
M·A·N

1019/58

Dam crest crane of 160 tons capacity for moving the emergency gates of 3.05 x 6.59 m against a water head of 95 m, for the Dokan Dam, Iraq.

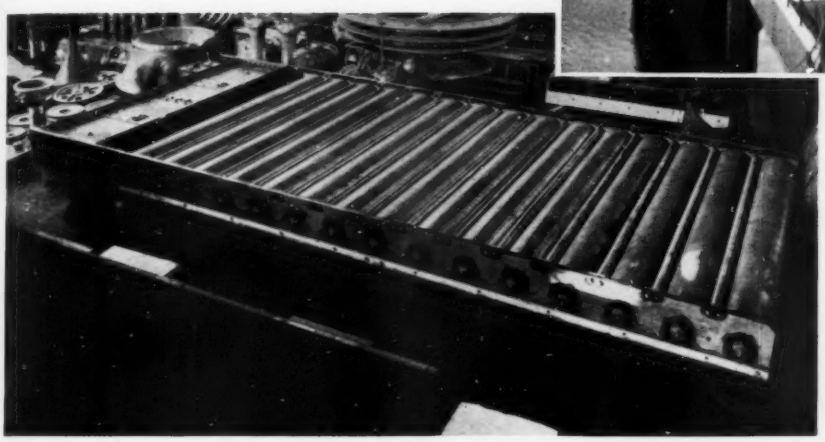
HYDRAULIC STRUCTURES

MASCHINENFABRIK AUGSBURG-NÜRNBERG AG · GUSTAVSBURG WORKS
GUSTAVSBURG/HESSEN (GERMANY) REPRESENTATIVES IN ALL COUNTRIES


KVÆRNER
Runner and shaft for
Upper Vinstra Power Plant,
rated output 92,000 H.P.,
428 rev./min.,
mean net head 320 metres.
Kvaerner Brug has delivered
Francis turbines for
heads up to 543 metres.
A. S. KVÆRNER BRUG, OSLO, NORWAY

Glenfield Gates

for Emergency Shut-off



FREE ROLLING TYPE

The pre-eminent design for rapid and certain emergency closure of culverts, or tunnel or turbine intakes.

The Gate, a Glenfield development that has been very widely applied, closes under the action of gravity only, even under free discharge conditions irrespective of the upstream head, and can be cracked open by the lifting mechanism against full unbalanced conditions without the use of any form of bypass.

Glenfield

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Head Office and Works: Kilmarnock · Scotland

All types of

mechanical handling plant

. . . screens, trash rakes and cranes for hydro-electric intake works . . .

Strachan and Henshaw Ltd

STEELHOIST WORKS
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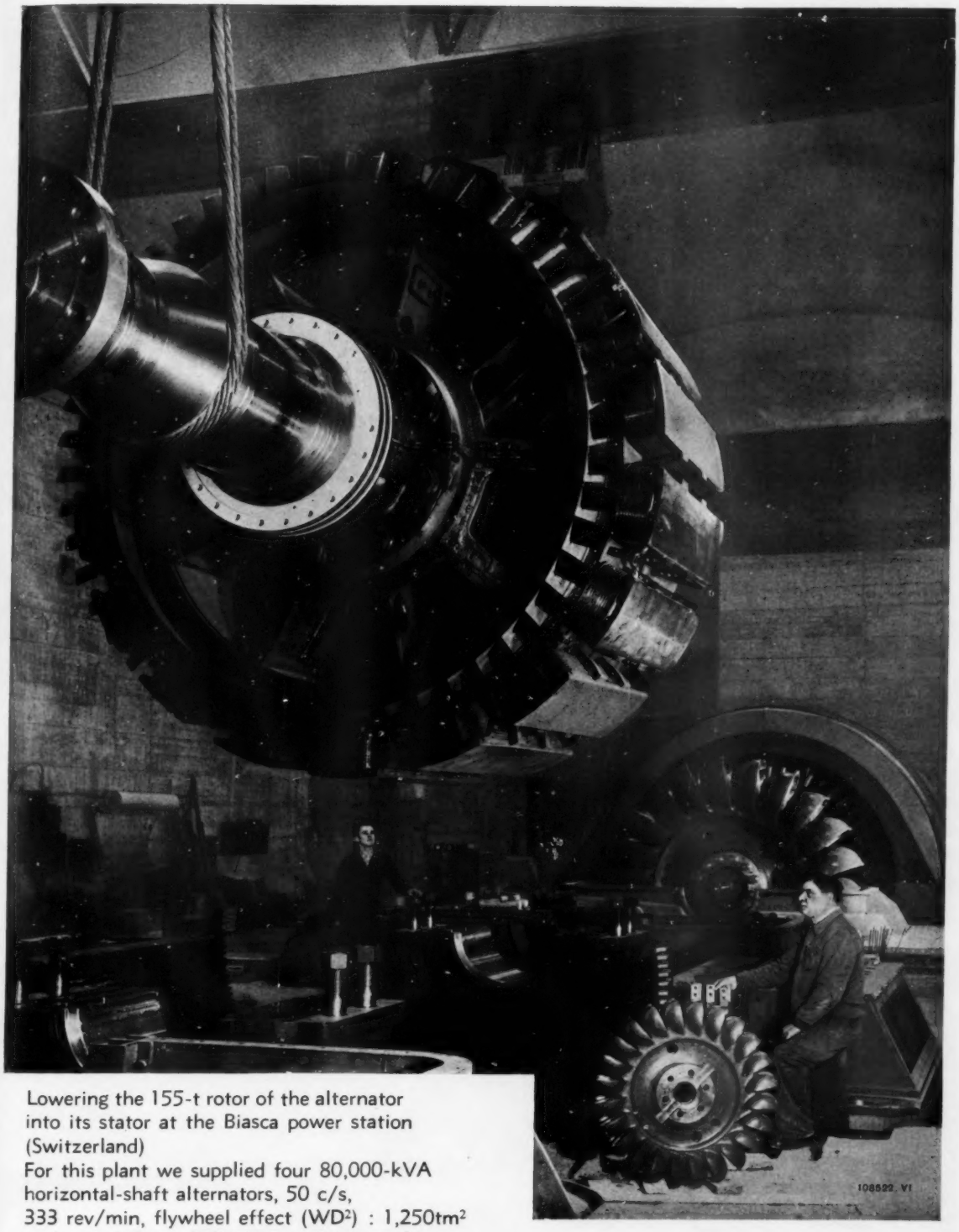
TELEPHONE BRISTOL 78331

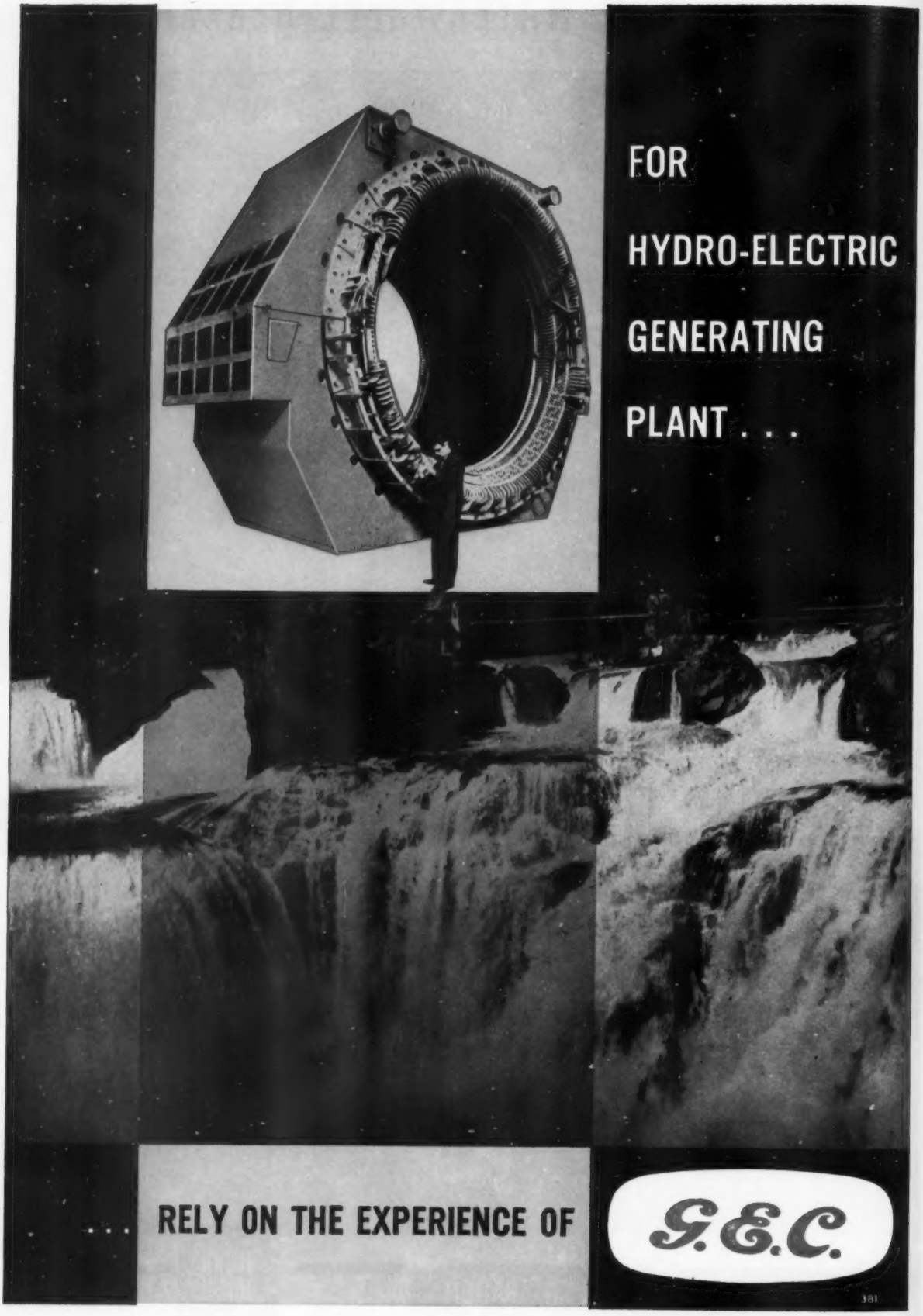
BROWN BOVERI WATERWHEEL GENERATORS



Lowering the 155-t rotor of the alternator into its stator at the Biasca power station (Switzerland)
For this plant we supplied four 80,000-kVA horizontal-shaft alternators, 50 c/s, 333 rev/min, flywheel effect (WD^2) : 1,250tm^2 each coupled to a 100,000 h.p. Pelton turbine

BROWN, BOVERI & CO., LTD., BADEN
SWITZERLAND

BROWN BOVERI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GENERATING
PLANT . . .
. . . RELY ON THE EXPERIENCE OF
G.E.C.
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The Steel foundry for water turbines

We supply turbine manufacturers, for the highest heads and outputs, with Pelton wheels, Francis runners, Kaplan blades and many other turbine components cast in **+GF+** Electric Steel alloyed or unalloyed.

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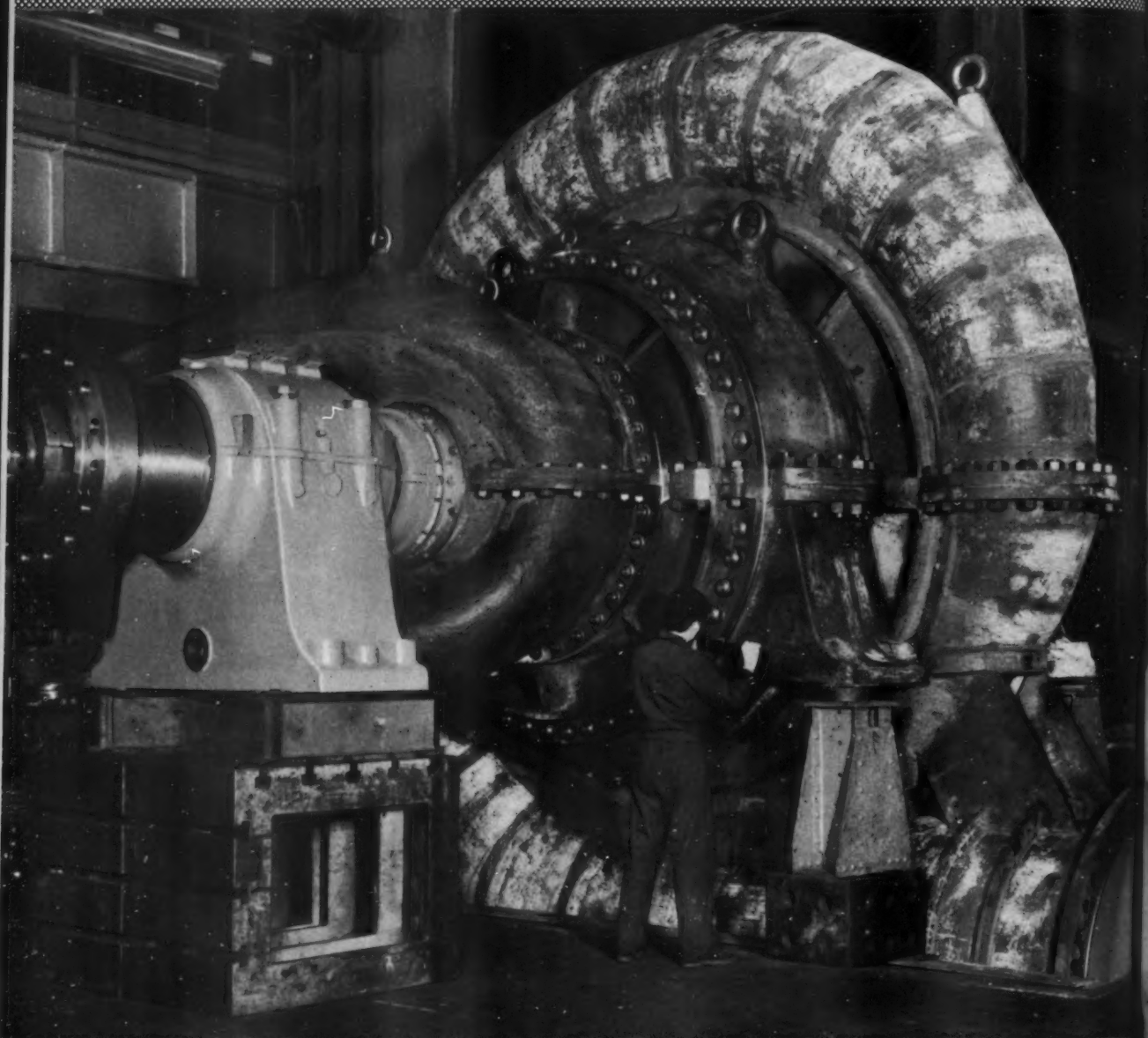
SOCIETA' GENERALE ELETTRICA DELLA SICILIA

GUADALAMI SCHEME

WE ARE SUPPLYING FOR THIS PROJECT:

- TWO 40,000 h.p. STORAGE PUMPS
- TWO 43,000 h.p. FRANCIS TURBINES
- ONE 31,000 h.p. FRANCIS TURBINE



RIVA

COSTRUZIONI MECCANICHE RIVA

VIA STENDHAL 34 MILANO ITALY

DREES

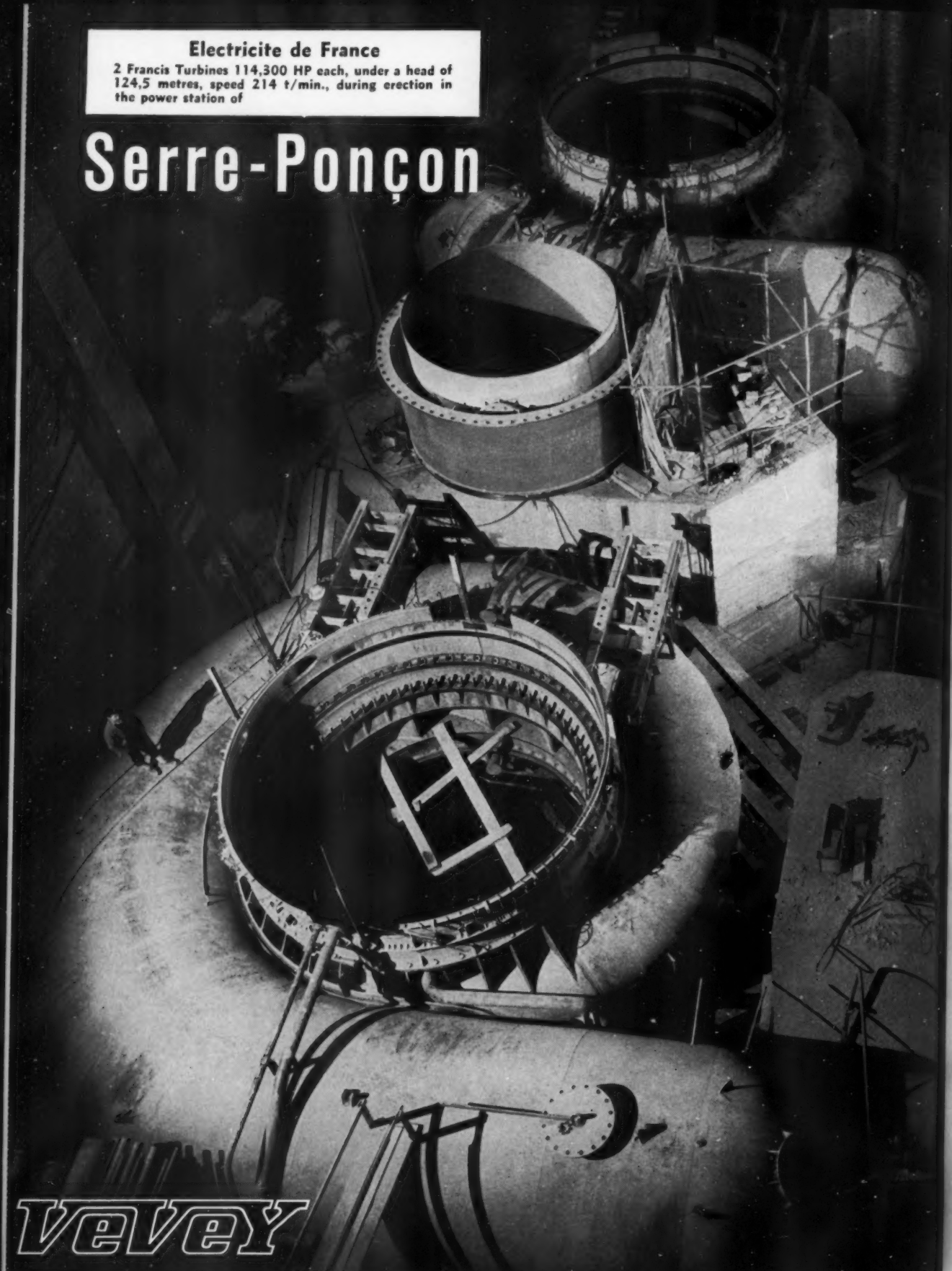
HYDRO-ELECTRIC UNIT

DREES u. CO. GMBH. ABT. 15, WERL GERMANY

Electricite de France

2 Francis Turbines 114,300 HP each, under a head of 124,5 metres, speed 214 t/min., during erection in the power station of

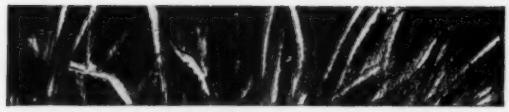
Serre-Ponçon



Vevey

Vevey Engineering Works Ltd.
Vevey (Switzerland)

in collaboration with our French licensee:
Cie des Ateliers et Forges de la Loire, St-Chamond (Loire)

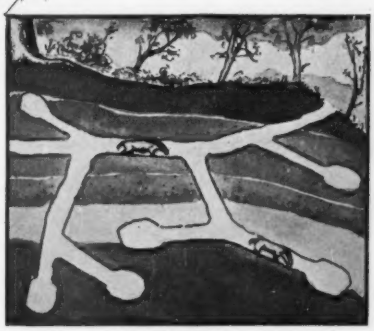


Underground movement

A long tunneller and a strong tunneller, the badger builds himself an intricate web of passages and dens in which to evade pursuit or retire from the noisy world outside.

It's a paradox of progress that man too—in getting even further away from nature—is going more and more underground. Tunnels for hydro-electric schemes, underground power houses—these and many other engineering feats are the work of man the tunneller—a skill which we have developed into a fine art. * *

* * In driving 40 miles of tunnels for the North of Scotland Hydro-Electric Board, Mitchell Construction captured and hold the World high speed rock-tunnelling record and constructed the first major underground power station in Britain.



Many of these badger 'sets' have been enlarged and improved through successive generations and may extend for hundreds of feet into a hillside.

MITCHELL CONSTRUCTION

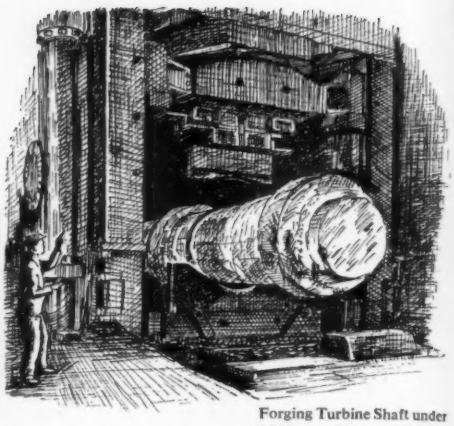
Building and Civil Engineering Contractors

THE MITCHELL CONSTRUCTION COMPANY LIMITED

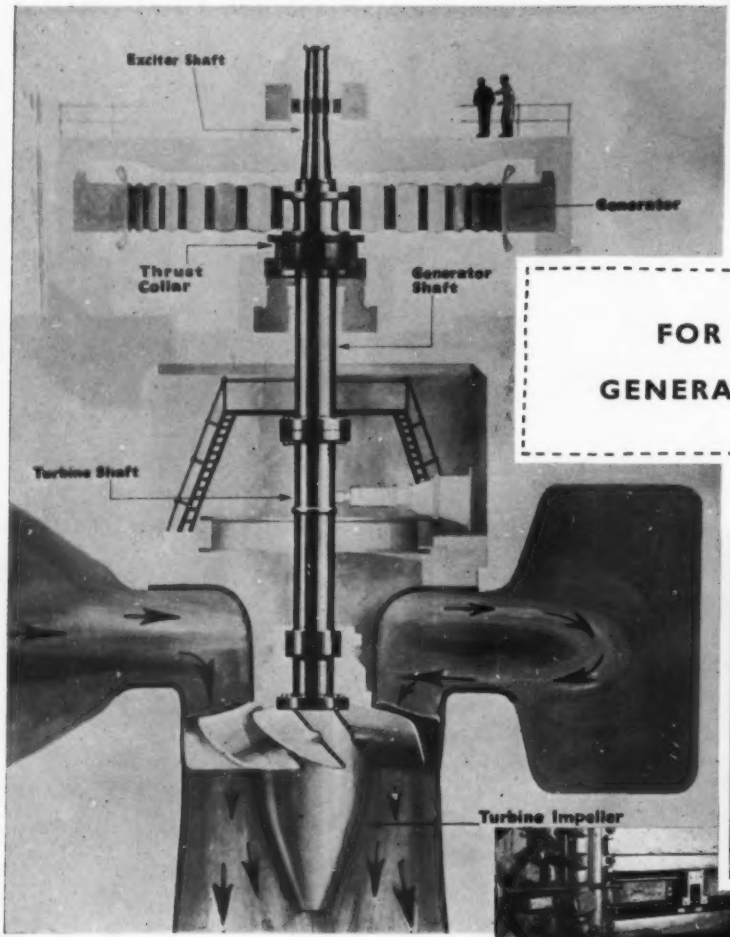
WHARF WORKS · PETERBOROUGH

P.2.51

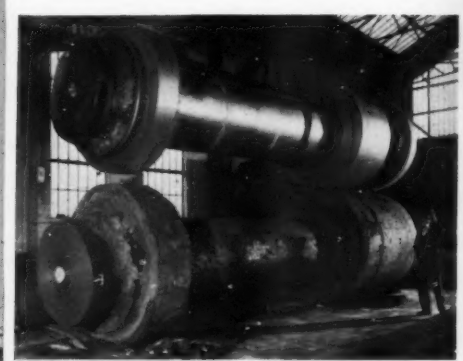
Steel Forgings...

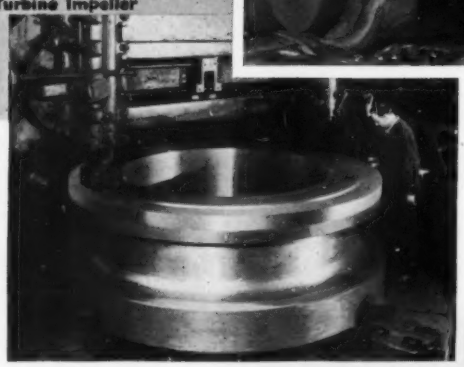


Forging Turbine Shaft under 7,000 ton Electro-hydraulic press.



FOR HYDRO-ELECTRIC GENERATOR INSTALLATIONS

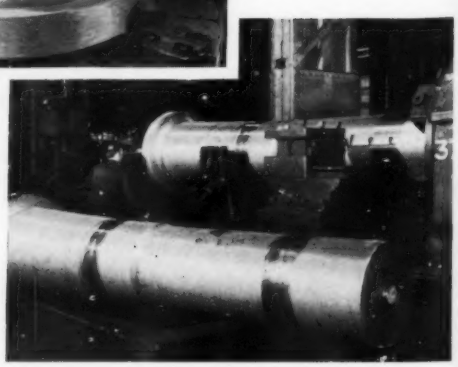




Rough machined and black forged steel Turbine Shafts, 22′ 11″ long.

Machining forged steel Thrust Collar, weight 18¼ tons.

Forged steel Exciter Shafts, each weighing 8¼ tons.



. . . in our high quality carbon and alloy steels — single piece engineering units up to 175 tons produced from ingots weighing up to 300 tons.

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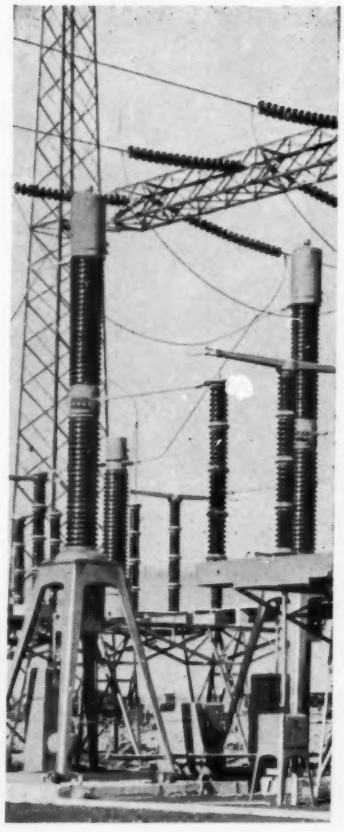
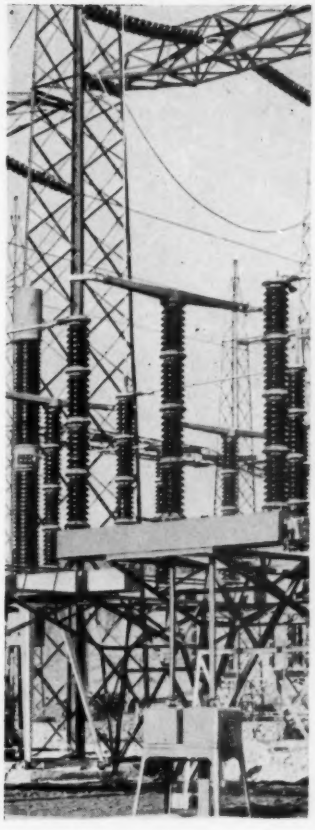
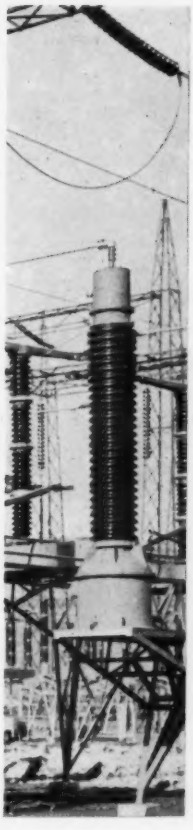
FORGE AND ENGINEERING CORPORATION LTD

River Don Works, Sheffield

A wholly owned subsidiary of English Steel Corporation Ltd







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MILANO VIA LARGA 26 (ITALY)

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INSTRUMENT TRANSFORMERS
ISOLATING SWITCHES
BUSHING INSULATORS
SWITCHBOARDS
METAL-CLAD SWITCHGEAR

FOR MEDIUM, HIGH
AND ULTRA-HIGH VOLTAGES

SWEDISH LADDER

New drifting technique doubles drill-crew output

Controlled feed · guided collaring · mechanical retraction— so one man can operate two rigs

NORTHERN SWEDEN has been the proving ground of a revolutionary rock drilling method which has opened the way to a completely new conception of drill-crew output. Known as the Swedish Ladder Drilling Method, this new technique has been employed on hydro-electric projects at Korsselbränna and Stalon where drilling platforms with 16 rock drills operated by 8-man drill crews have been used.

Atlas Copco drills mounted on retractable pusher legs* are rested in cradles running horizontally in "ladders". Contractors and drill crews have found that these rigs, cheaply and simply constructed, offer the following advantages:

INCREASED PENETRATION—full feed power is ensured by the ideal horizontal feeding position of the pusher leg.

HIGHER OUTPUT PER MAN/HOUR—due to greater penetration and the fact that *one man handles two drills.*

REDUCED CREW FATIGUE—collaring is made simple as operators need not hold the drills. Drill steels are mechanically withdrawn from holes using the retractable pusher leg.

FEWER DRILL STEEL CHANGES—long steels can be used from the start. For greater durability 1″ Sandvik Coromant integral steels are used.

GREATER DRILLING ACCURACY—thanks to the fixed ladder base and pre-positioning of drills for pattern drilling.

DRILLING METHOD

DRAMATIC RESULTS OF LADDER DRILL TESTS

The figures show the dramatic increase in drilling achieved by ladder rigs in a 60 sq.m. tunnel at Stalon driven in hard-drilled quartzite. Gross effect refers to the mean value for the whole drilling period, including collaring, changing steels and the usual routine delays. *Note that the gross effect is exactly doubled.*

GROSS EFFECTS

[redacted]

19.5 metres/man-hour Conventional drilling with one rock drill

[redacted]

39.0 metres/man-hour Ladder drilling with two drills

AVAILABLE FROM ATLAS COPCO

The Swedish Ladder Drilling Method was originally introduced by Widmark and Platzer, one of Sweden's leading contracting companies, and has been further developed by them and by the Swedish State Power Board. Specially evolved with Atlas Copco trigger-operated retractable pusher legs*, this method and equipment has been exhaustively tested and proved under tough Swedish drilling conditions. There are Atlas Copco companies or agents in ninety countries and details of the new equipment are readily available from them or from the address below. Wherever you are, the international Atlas Copco group offers expert advice on the selection of equipment and a complete after-sales service.

WRITE FOR THE BOOKLET! The Swedish Ladder Drilling Method is described in greater detail in a new Atlas Copco booklet. Write for a copy to your local Atlas Copco company or agent or from the address below.

* Patents pending

Atlas Copco

PUTS COMPRESSED AIR TO WORK FOR THE WORLD

ATLAS COPCO AB, STOCKHOLM 1, SWEDEN

SOCIETE DES FORGES ET ATELIERS DU CREUSOT (USINES SCHNEIDER)
15, Rue Pasquier, PARIS 8e - Tél. : Anjou 34-40

LE MATERIEL ELECTRIQUE S-W
Constructions électriques SCHNEIDER
Licence WESTINGHOUSE
32, Cours Albert-1er PARIS 8e Tel. BAL 57-50

COMPAGNIE INDUSTRIELLE DE TRAVAUX (ENTREPRISES SCHNEIDER)
16, Boulr Malesherbes, PARIS 8e - Tél. : Anjou 34-40

Laksapana Power Plant (Ceylon): Penstocks

Serre-Ponçon Dam Project : concrete gallery extending over 7,000 ft.

Laksapana Power Plant : Two 16,100 kW Pelton units under erection

CONSTRUCTION AND ERECTION OF ANY HYDRAULIC POWER PLANT EQUIPMENT

Penstocks, Valves, Turbines, Alternators, Electric Switchgear, Transformers, etc...

CIVIL ENGINEERING WORK

Penstock and Gate

We specialize in . . .

DESIGNING
MANUFACTURING
ERECTION

Established: 1904

SAKAI IRON WORKS CO., LTD.

HEAD OFFICE: NISHI, 6-CHOME, TSUMORI-CHO, NISHINARI-KU, OSAKA, JAPAN CABLE ADDRESS: "SAKATETSU OSAKA"

TOKYO OFFICE: NIHONBASHI-GOFUKUBASHI, CHUO-KU, TOKYO, JAPAN CABLE ADDRESS: "SAKATETSU TOKYO"

"still giving excellent service after 36 years"—that's the report from Arkansas Power & Light on three Leffel Turbines at Remmel Dam

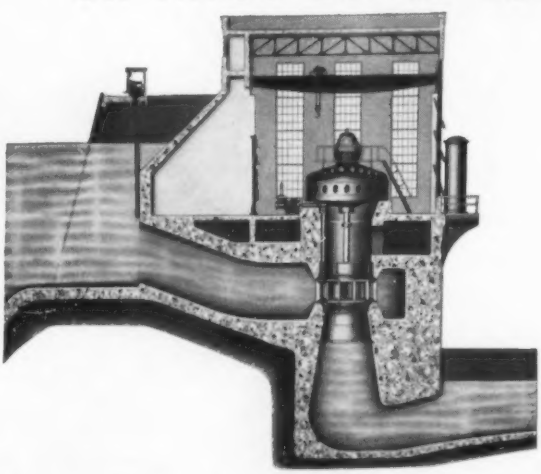


Photo above shows Remmel Dam as it appears today. The dam is located on the Ouachita River near Hot Springs, Arkansas. Seventy-five feet high and 900 feet long at the apex, it creates Lake Catherine, with a total area of 2624 acres. Drawing shows a cross-section of the Remmel Dam power house, unusual in that the turbines are installed at a height of 19' above tail water.

In 1924, three Leffel vertical shaft turbines were installed at the Arkansas Power & Light Company's Remmel Dam hydro-electric station . . . Arkansas's first major hydro-electric facility.

In addition to the three turbines, each rated 5700 H.P. at 120 R.P.M. under a 50 foot net head, Leffel also furnished the outside gate equipment for the Remmel Station.

Arkansas Power & Light's report, after 36 years of operating experience, boils down to "very well pleased with the equipment, which is still operating satisfactorily . . . very little in the way of repairs required during the 36 years."

An unusual case? Not for Leffel. Long life and reliable service are the routine, not the exception for Leffel turbines. That's why satisfied Leffel customers in all parts of the world, like Arkansas Power & Light, will turn to Leffel for help on their next hydro-electric project, whether it be a completely new installation or the rehabilitation or expansion of existing facilities.

You, too, can take advantage, without obligation, of Leffel's nearly a century of experience in designing and building fine hydraulic turbines. Just drop us a line outlining your requirements, or the nature of your water power problem.

1114-E

FOUNDED IN 1862

THE JAMES LEFFEL & CO.

DEPARTMENT W • SPRINGFIELD, OHIO, U. S. A.

MORE EFFICIENT HYDRAULIC POWER FOR 98 YEARS

START A COST-FOR-COST ENQUIRY

*DID YOU KNOW

a BRECO Ropeway can carry
a ton for a mile for a penny?

* WE WOULD BE PLEASED TO SEND DETAILS
OF A ROPEWAY, AS APPLIED TO YOUR INDUSTRY.

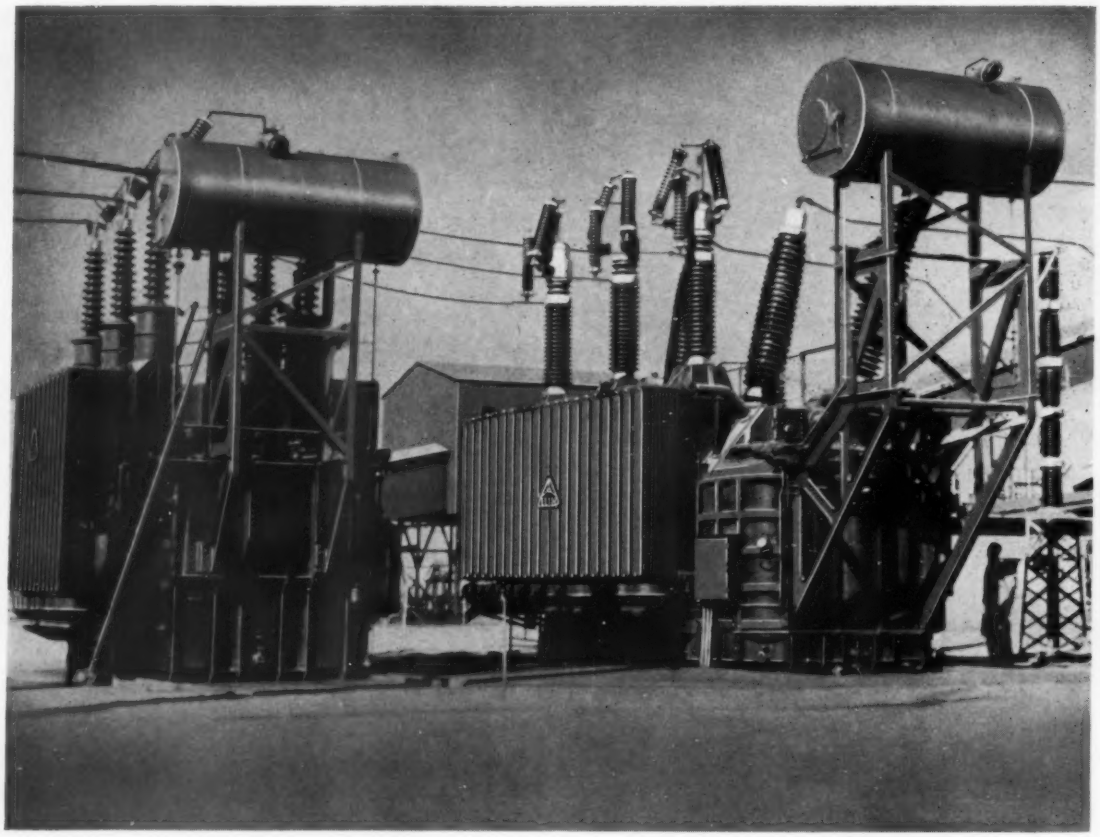
BRECO

member of the Glover Group

THE BIG NAME BEHIND THE BIG ROPEWAYS

BRITISH ROPEWAY ENGINEERING CO. LTD. PLANTATION HOUSE, MINCING LANE, LONDON, E.C.3. *Tel: MINcing Lane 7901. Telegraphic Address: BOXHAULING, FEN, LONDON*

TRANSFORMERS BY ELIN-UNION



Group of three-phase transformers with a throughput of 60,000 kVA for in-phase and quadrature regulation in separate units; in-phase ratio 284,000 V ± 12 x 3,440 V / 132,000 V, quadrature ratio 132,000/ 132,000 V ± 16 x 3,330 V. The in-phase regulator shown right in the illustration is fitted with four-conductor condenser bushings and surge diverters. The Client is the Electricity Trust of South Australia.

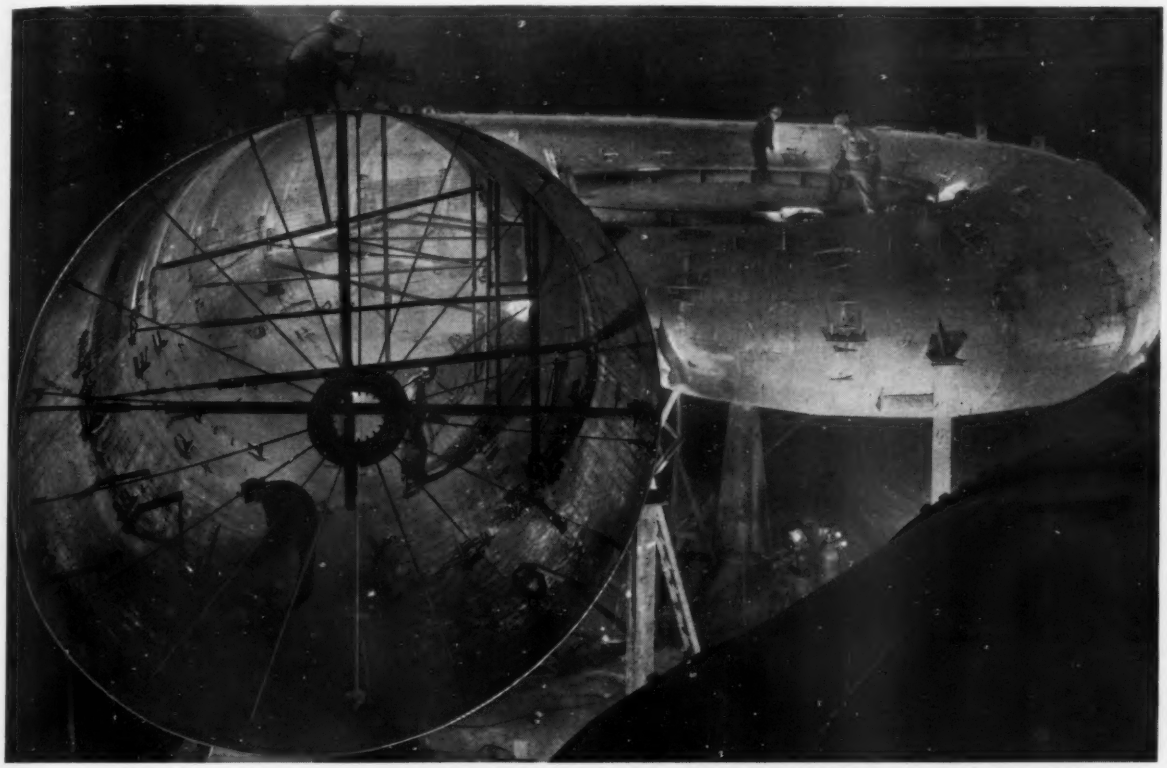
ELIN UNION

Aktiengesellschaft für elektrische Industrie

Zentrale: Wien I., Volksgartenstrasse 3

ALLIS-CHALMERS

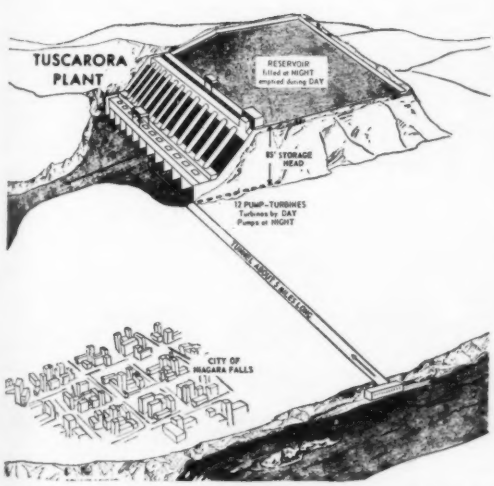
A-1231



THE BIGGEST MADE IN THE U.S.A., this reversible pump-turbine scroll case has inlet diameter of 18 ft, measures 56 ft across. It's designed for one of Tuscarora's 12 Allis-Chalmers pump-turbines.

Now building 12 reversible pump-turbines for Tuscarora—

world's largest pumped-storage project



Power plant by day, pumping station at night — the New York State Power Authority's Tuscarora plant will capitalize on the hydroelectric power potential of the Niagara River without adversely affecting the scenic beauty of the Falls.

The largest project of its kind, Tuscarora will have 12 reversible pump-turbines . . . all designed and fabricated by Allis-Chalmers. As a turbine, each of these units is rated at 28,000 hp under 75-ft head. In reverse, as a pump, each is rated at 3400 cfs against 85-ft head. All will be direct-connected to Allis-Chalmers generator-motors — rating 25,000 kva at .8 P.F. as generators . . . 37,500 hp at 100% P.F. in reverse as motors.

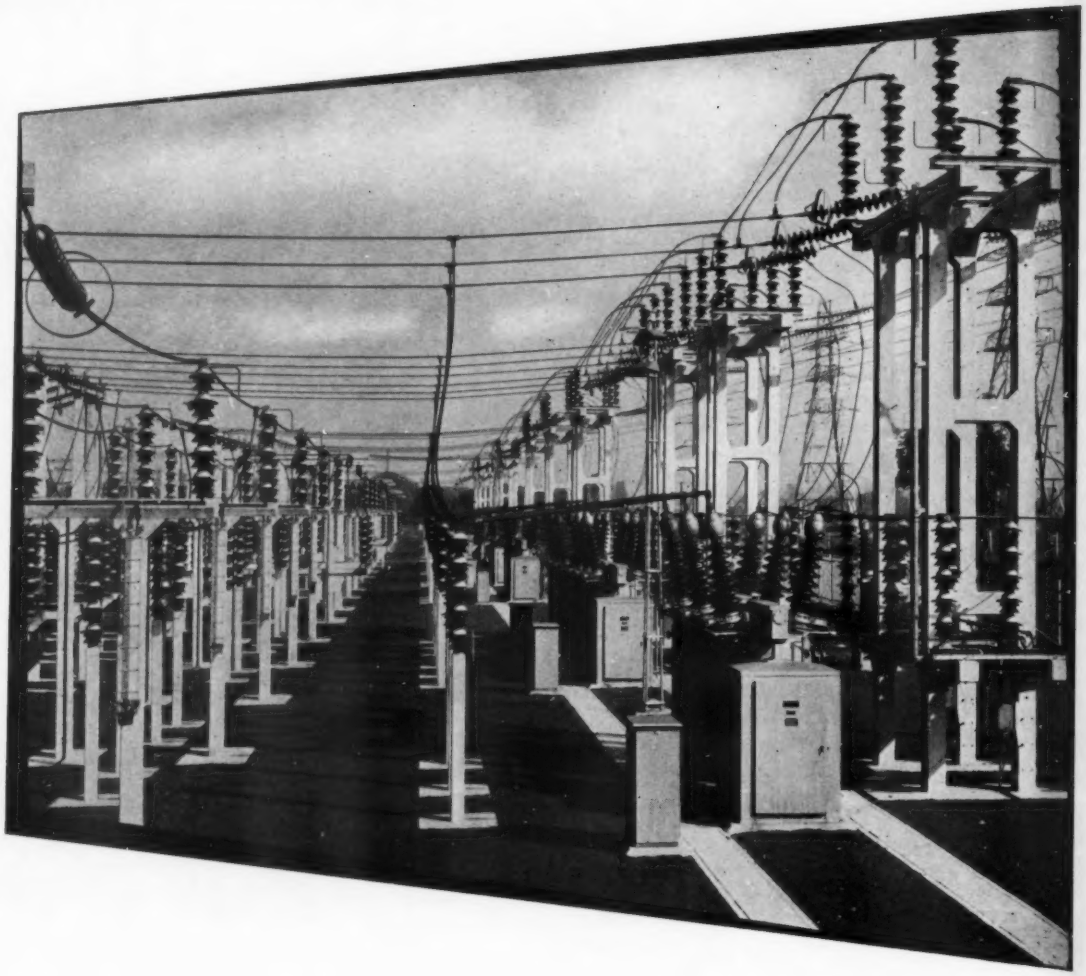
The selection of Allis-Chalmers to design and build the above components came naturally. A-C is the only builder of complete reversible pump-turbine installations — with a record that includes the world's largest pumped-storage projects.

Look to Allis-Chalmers for leadership in the design, engineering and manufacture of hydraulic turbines and necessary accessories such as valves, pumps, trash rakes, water control gates and hoists. *For information, contact your nearby A-C office . . . or write* ***Allis-Chalmers,*** *Hydraulic Division, York, Pa.*

Outside United States contact Allis-Chalmers International, or in Canada, Canadian Allis-Chalmers

DOULTON INSULATORS

designed for uninterrupted service



The Central Electricity Generating Board's Supergrid Substation at Penn, near Wolverhampton, has 132 kV isolators and busbars for which Doulton's supplied the post type insulators.

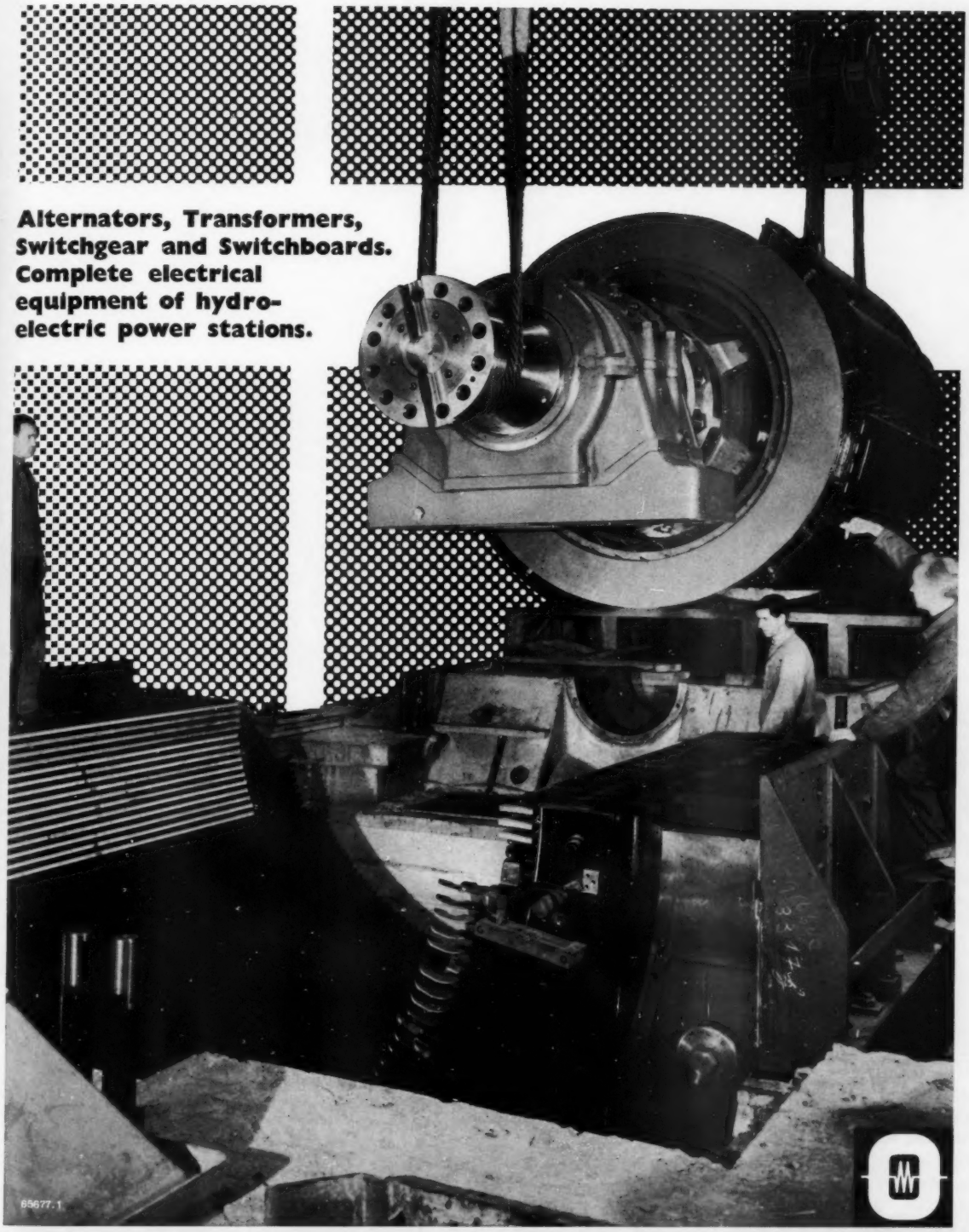
This Substation is a key point on the gigantic 275 kV "Ring Main" now being built round Birmingham and the Black Country.

Doulton's range of heavy duty posts also includes designs up to 400 kV.

DOULTON INDUSTRIAL PORCELAINS LIMITED

ROYAL DOULTON POTTERIES
WILNECOTE · TAMWORTH · STAFFS

Alternators, Transformers, Switchgear and Switchboards. Complete electrical equipment of hydro-electric power stations.



Oerlikon Engineering Company • Zurich 50 (Switzerland)

modern control

sets a new standard

of electric operation

ONLY BUCYRUS-ERIE EXCAVATORS INCORPORATE THIS NEW CONTROL

A few of the facts:

No excessive heat loss, even in stall conditions.

Torque increase; speed reduction, in heavy digging operations.

Gradual turns are possible in either direction, without forward-reverse jockeying—even on hard quarry floors.

No operating clutches. Separate power sources are used to control each specific operation. Full power up and power down for hoisting and lowering.

Crowd machinery is mounted on the revolving frame—not on the boom—so that the weight is effectively used without reducing front-end output. Digging ranges are greater than any other electric or diesel of similar capacity.

MORE FACTS about this new Bucyrus-Erie electric control are available on application.

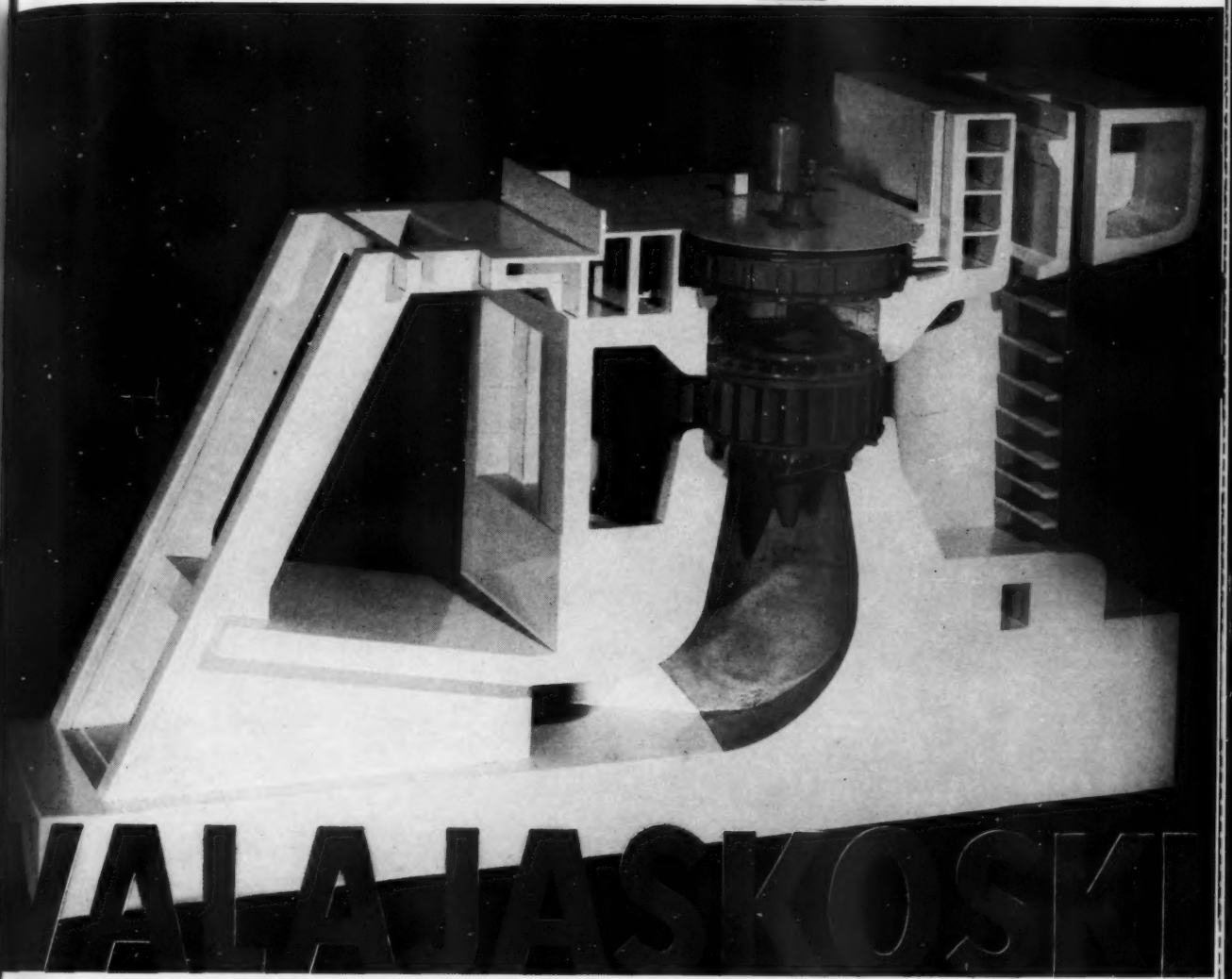
BUCYRUS ERIE

BUCYRUS-ERIE COMPANY

South Milwaukee, Wisconsin, U.S.A.

RUSTON-BUCYRUS LIMITED, LINCOLN, ENGLAND

Finland's largest turbine



Miniature model of the Valajaskoski turbine and its concrete construction.

The outer periphery of the runner blades is being turned. The runner diameter 6750 mm. is hitherto the largest in Finland.

Valajaskoski, one of the power plants in the biggest river of Finland, the Kemi River, is now being completed. For this plant, 2 Kaplan turbines have been delivered by Tampella, each with the following technical data:

H = 11.2 m. Q = 250 cu. m./sec.
N = 33,900 H.P. n = 75 R.P.M.

Tampella

TAMMERFORS LINNE- OCH JERN-MANUFAKTUR AKTIEBOLAG
Engineering Works
Established 1842
TAMMERFORS · FINLAND

WAAGNER - BIRO

For the Bhakra Dam in India . . .

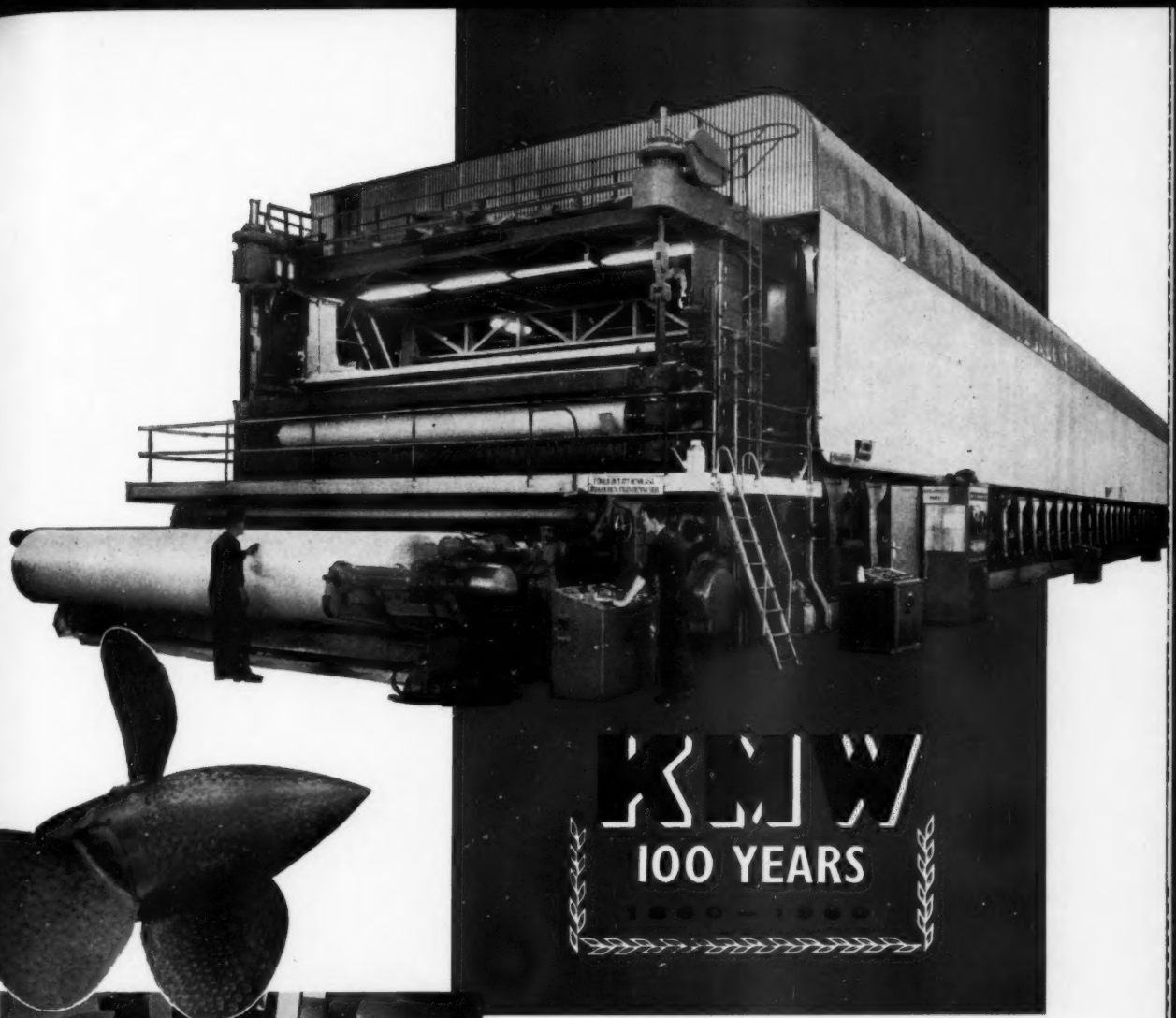
We have supplied:

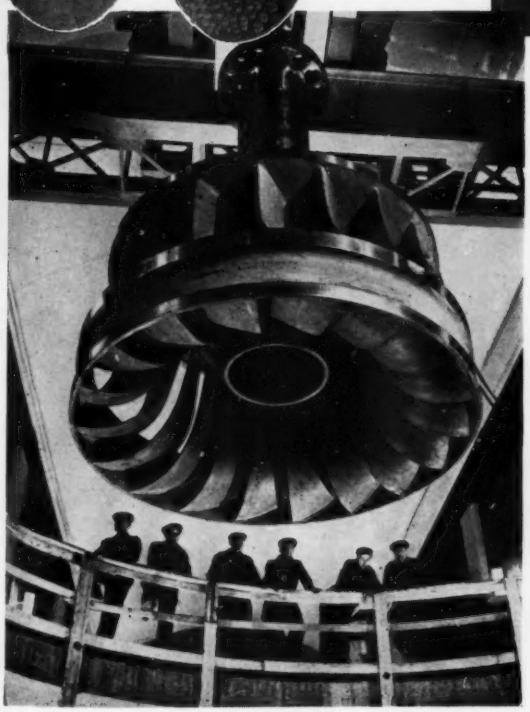
TUNNEL GATES

TURBINE INTAKE GATES and

OIL OPERATED SERVO-MOTORS

Head Office: VIENNA V., MARGARETENSTRASSE 70, AUSTRIA





This year AB Karlstads Mekaniska Werkstad—a Swedish heavy industry with world-wide fame—enter into a new century of activity. In 1860 a small machine-shop and foundry were established on the site of the present works at Karlstad. The firm attained its present status in 1873, and in the late seventies KMW began to manufacture the products which later made the firm's name known the world over, i.e., machinery for the pulp and paper industries.

Development proceeded rapidly, and in 1897 Kristinehamns Mekaniska Werkstad was purchased by KMW. The manufacture of water turbines was subsequently concentrated at Kristinehamn, and these products also became well-known all over the world. The third main branch of manufacture was developed in 1936 when KMW started to make controllable-pitch KaMeWa propellers, now delivered to a wide variety of ships of many nations.

The 100th anniversary celebration will include the completion of a new plate shop and a large new research laboratory for further development of KMW paper machines. For their other main products, water turbines and propellers, KMW have modern laboratories which are among the best equipped in the world.

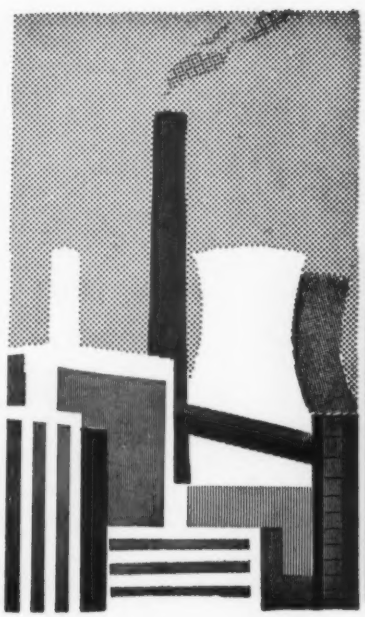
KMW is well equipped to meet a new century.

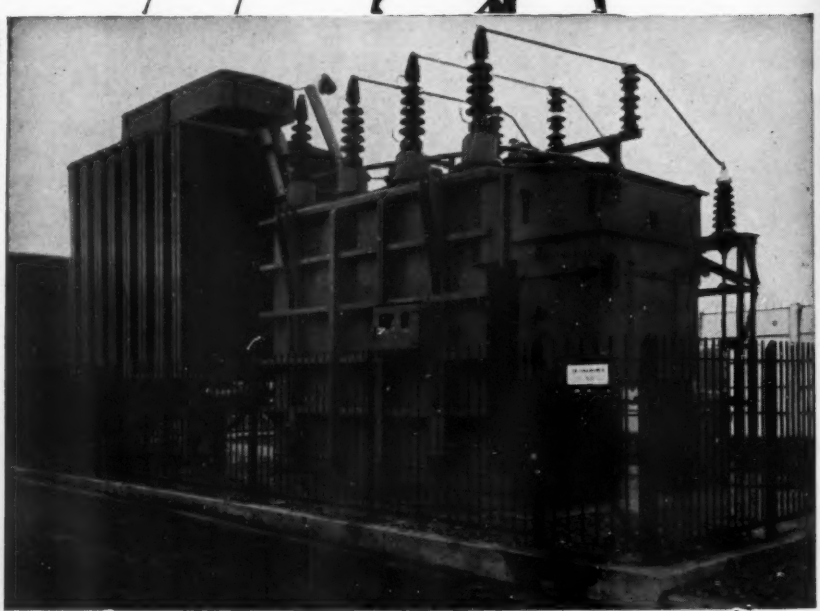
AB KARLSTADS MEKANISKA WERKSTAD

KARLSTAD · SWEDEN

YORKSHIRE *transformers*

serve the power supplies of Great Britain





YORKSHIRE ELECTRIC TRANSFORMER CO. LTD.
THORNHILL, DEWSBURY, YORKS., ENGLAND
Tel: Dewsbury 1691-2 Grams: Transforma, Dewsbury

TREATED WOOD STAVE PIPE FOLLOWS THE NATURAL GROUND CURVE IN JAMAICA

The wood components in this mile-long pipeline in Jamaica were pressure treated with creosote oil for durability. The pipeline follows the natural ground curve and was built with ease by local labour.

Through a wide range of sizes and pressures, wood stave pipe is the economical choice of engineers for high-line conduits, penstocks and irrigation projects.

Our recent publication: *CONTINUOUS STAVE WOOD PIPE*, reveals details of history, uses, construction and maintenance, together with design data and flow tables. Write for your copy.

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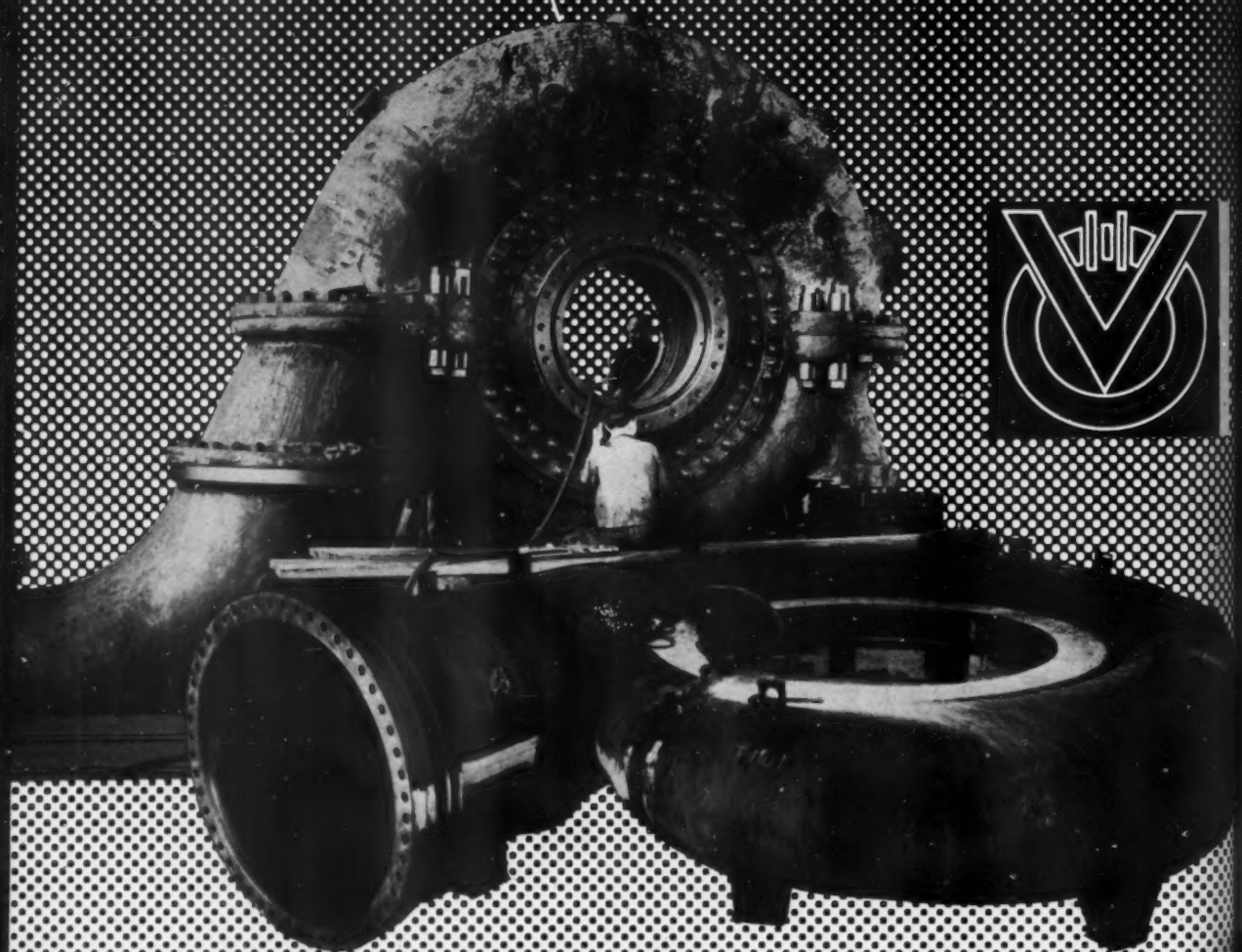
Vancouver 2, British Columbia,
Canada

VÖEST

Hydraulic Turbines, Spherical and Butterfly Valves

Licensed by Baldwin-Lima-Hamilton Corp.
Philadelphia, U.S.A.



VEREINIGTE ÖSTERREICHISCHE EISEN- UND STAHLWERKE, LINZ-DONAU, AUSTRIA

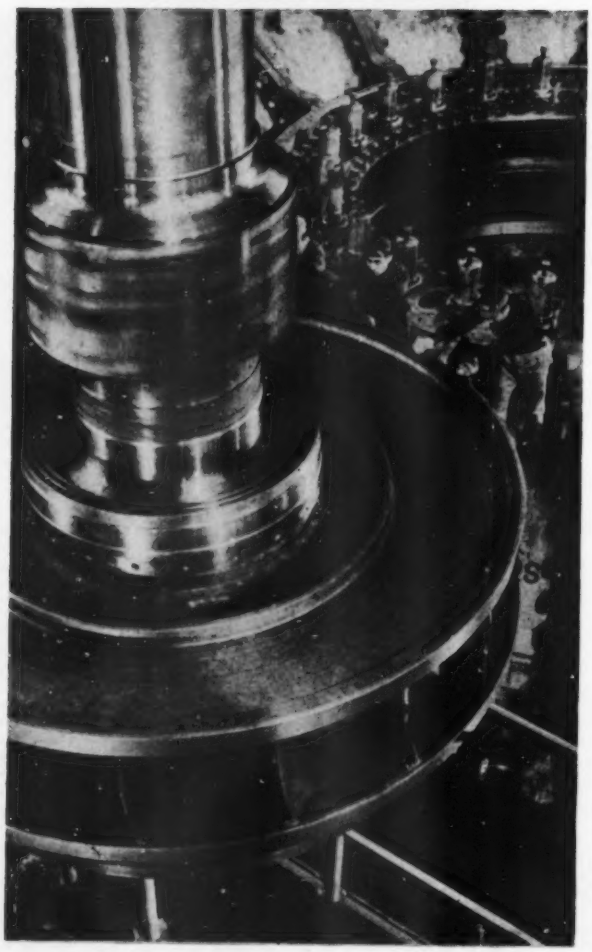
VÖEST

HYDRAULIC STEEL CONSTRUCTION

Steel structures for weirs and loch gates of every type, including the required auxiliary equipment; mechanical and hydraulic drives hereto sprocket chains; trash rake cleaning machines; weir cranes.

VEREINIGTE ÖSTERR. EISEN- UND STAHLWERKE, LINZ-DONAU

Toshiba



Contributing to Your Better Living!

Heavy electric equipment such as Water Turbines, Generators, Power Transformers, and testing equipment for Power Stations, are being shipped out one after another from Toshiba's Tsurumi works.

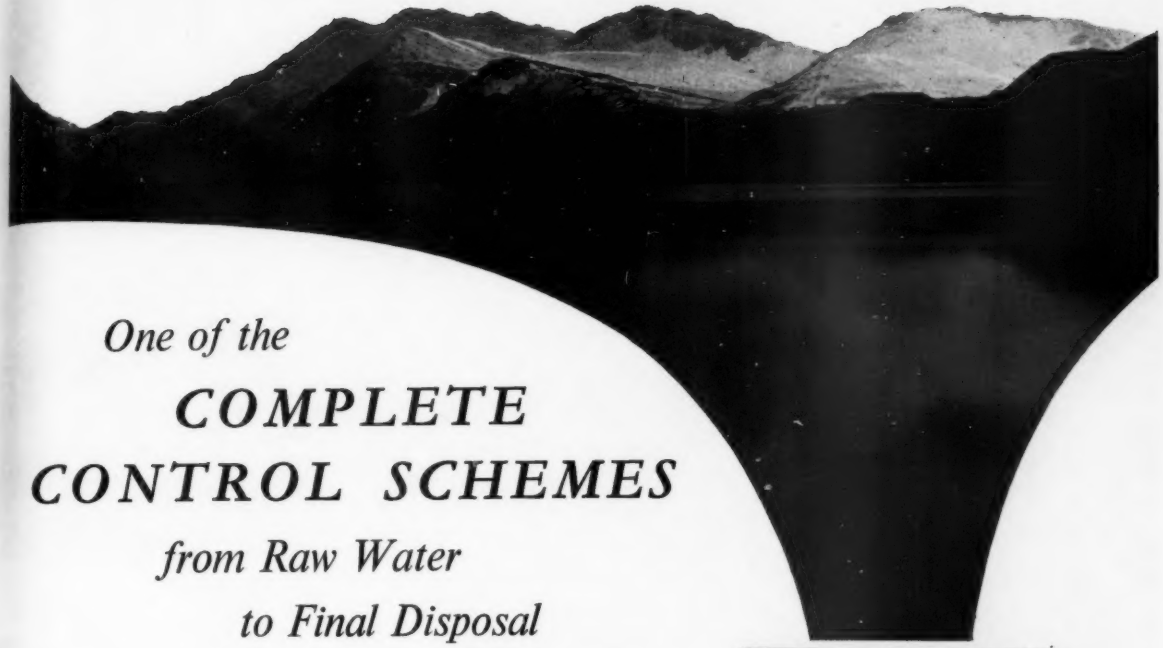
Shown above is one of the 3 scheduled 133,000 kVA generators—among the largest in the world—to be installed at Okutadami Power Station in central Japan.

The 137,000 KW Francis turbine, seen at left, to be coupled with this generator is also a Toshiba product. The runner diameter of this turbine is 4,000 mm, and ranks among the biggest in the world.

Similar generators with 58,000 kVA power has been installed at Mazatepec Power Station in Mexico and is now in full operation, Toshiba is also in production for various heavy equipment for many other new projects around the world.

Tokyo Shibaura Electric Co., Ltd.

2 Ginza Nishi 5-Chome, Chuo-ku, Tokyo, Japan
Cable Address: TOSHIBA TOKYO

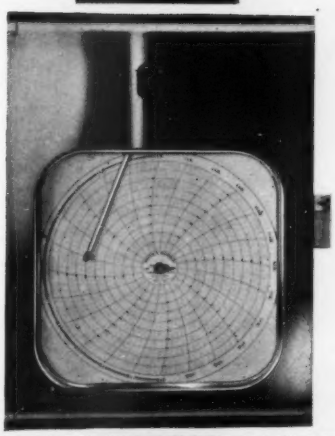


One of the

COMPLETE CONTROL SCHEMES

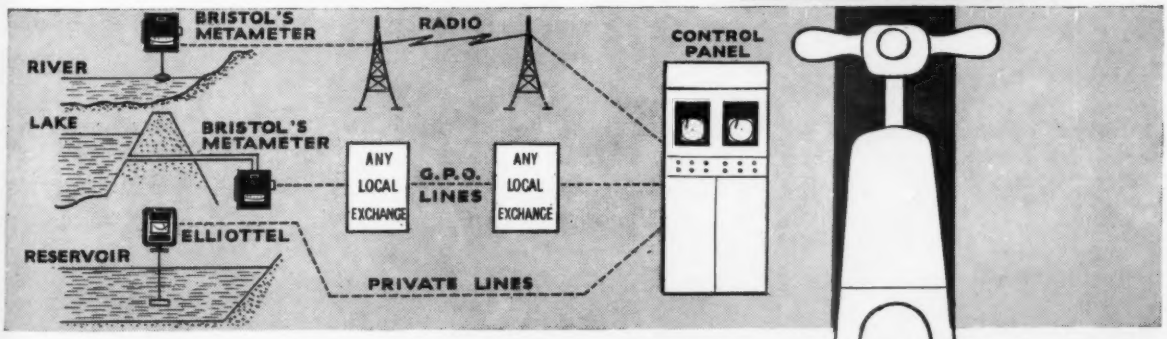
from Raw Water to Final Disposal

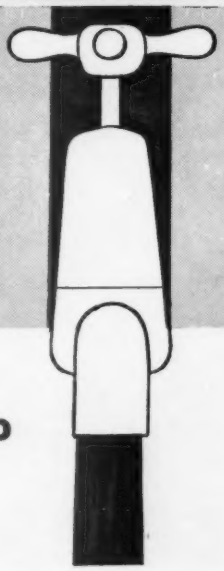
BY ELLIOTT



Heavy Loads on today's Water Schemes

The constantly increasing domestic needs and expanded industrial demands for water, have pushed the load on most water systems up close to their maximum capacities. *Operations at or near capacity make accurate, continuous measurement of water pressure, level and flow of the utmost importance.* As demands for water vary with the hour of the day, day of the week, and season of the year, pressures at the consumer's outlets will vary correspondingly unless they are constantly measured and effectively controlled.





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Water Industries Section

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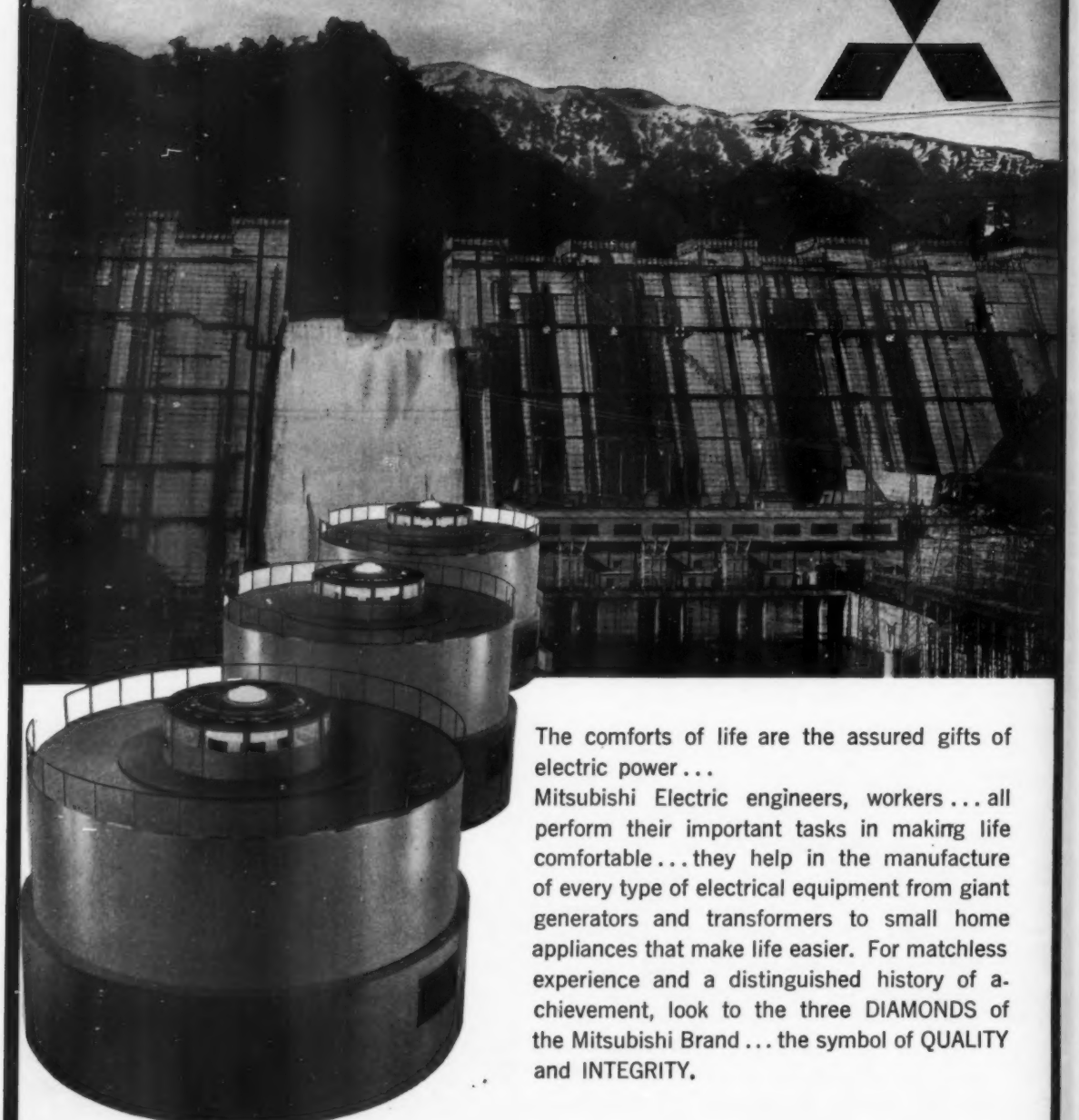

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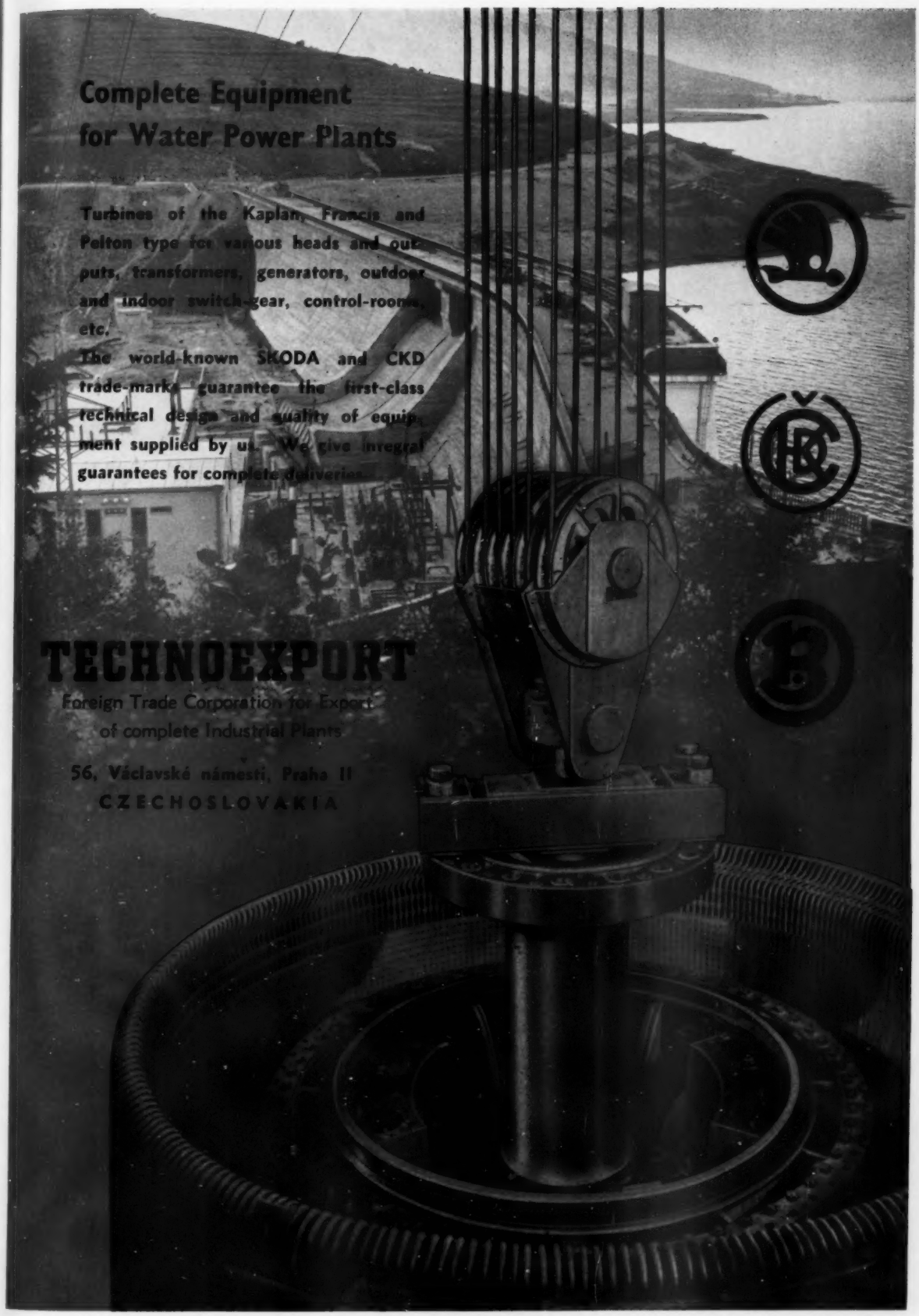
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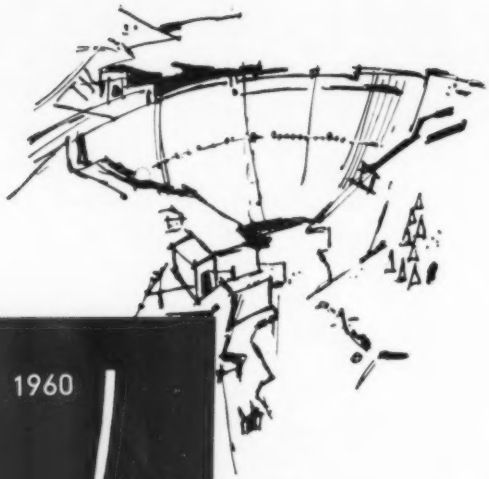

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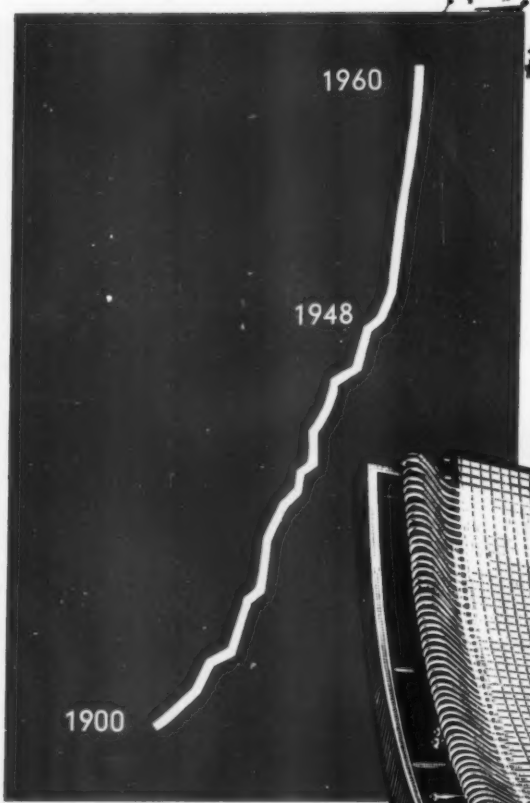

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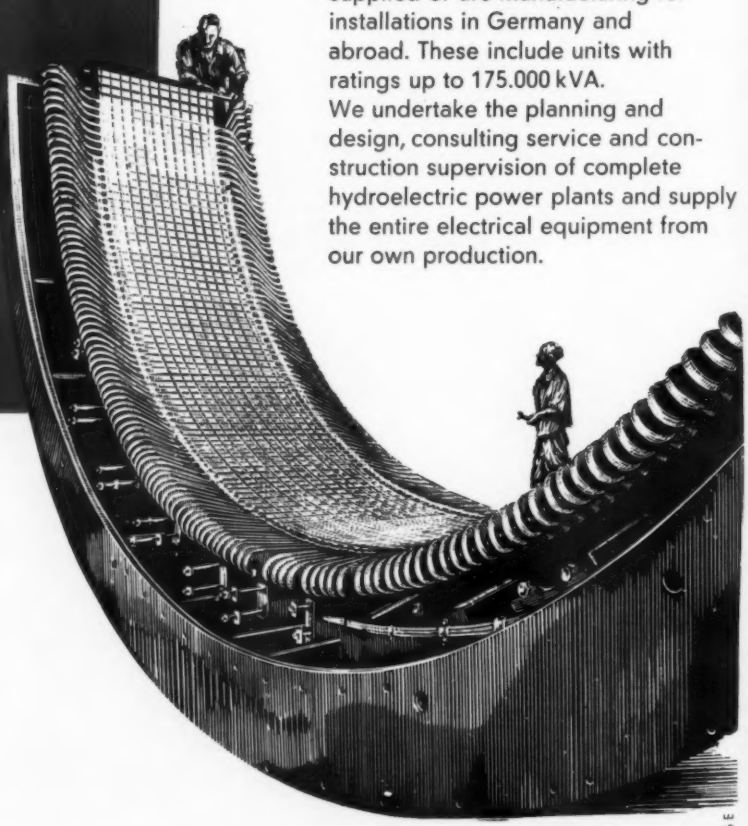

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WATER POWER

A technical journal devoted to the study of all aspects of hydro-electric development

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Volume 12 Number 10

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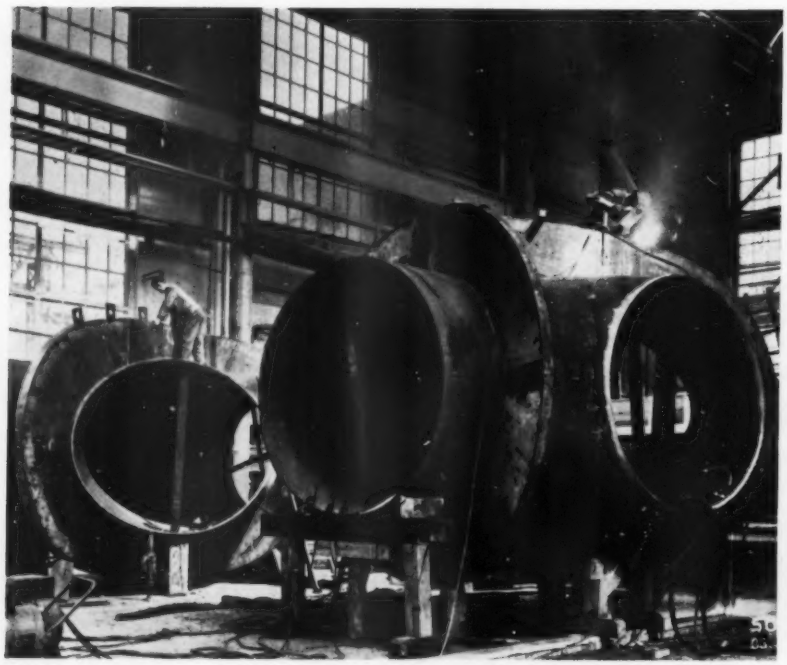
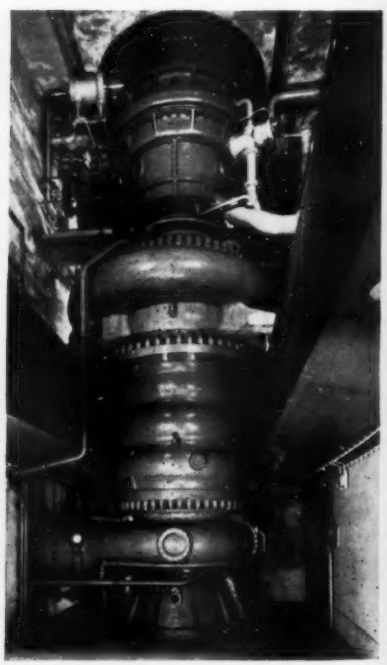


Fabrication of two branch pipes for Ffestiniog in the Sulzer shops at Winterthur. Inside diameter 7 ft. 6 in., service pressure 590 lb. per sq. in.



Sulzer five-stage high-lift pump in an Austrian power storage station. Discharge 49,250 g. p. m., head 3,186 ft., input 55,500 H. P.

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WATER POWER

A technical journal devoted to the study of all aspects of hydro-electric development

A New Look at Pumped Storage

IN recent years the wider use of pumped storage has been advocated for several reasons, chief among them being the need for a perfect partner for nuclear plants, and the general requirement that the load factor of any system shall be improved by any available means.

As a journal concerned exclusively with hydro-electric development we have long been convinced of the value of pumped storage, and we believe that pumped storage will form an essential feature of the power-supply pattern of the future. Nevertheless, it is not unusual for a new development of far-reaching consequence to be attended by a wave of over-optimism—witness nuclear power—and it is wise to be on our guard against a similar eventuality in the case of pumped storage. Over-optimism in its turn tends to be succeeded by over-caution, and there were indications of such a change of emphasis at the recent Madrid meeting of the World Power Conference. Some valid points were raised, however, which deserve to be placed on record.

Those who have advocated pumped-storage plants have naturally stressed the fact that energy used in such schemes for pumping is "excess" energy; but the recent World Power Conference papers showed that this word "excess" may involve an over-simplification. Only when certain complex conditions of system operation are fulfilled can such energy be called excess. In a network where thermal plant of various efficiencies and sizes is in operation, and where (in the future) gas turbines and other special plant may be used for peaking purposes, it was seen from the discussions that pumping energy can only be taken from the system at minimum cost when the remainder of the plant is in such an operational state, and is so completely interconnected, that certain marginally operative advantages obtain. Taken at other times, such energy may have a real cost which tends to disturb sensibly the cost-comparison arguments on which the whole scheme was based. And it does not follow that every pumped-storage installation can be so designed as to take in pumping energy at a time dictated not by hydraulic conditions associated with the plant itself but by the complexities of operation of a remote and mixed power system.

On the side of capital cost of pumped-storage schemes, a German paper presented to the Conference indicated that a scheme was likely to be economic if its cost per kW did not exceed the cost per kW of a comparable thermal station by more than a factor of 1·3 to 1·4. But a British view, expressed by Mr. Clark of the Central Electricity Generating Board, was that the economic attraction would only have sufficient pull to be practicable if this factor were less than unity—that is, if the cost were in fact less per kW for pumped storage than it was for steam plant. However, he went on to say that as steam plants become larger, the progressive increase in thermal efficiency would become less; and as that trend stood revealed the advantages of pumped storage would begin to stand out more clearly.

Another point in considering the relative economics of pumped-storage plants in comparison with other forms of peak-load plant is often slurred over in argument. The efficiency of a pumped-storage plant is often given as a fixed figure, say between 70% and 75%. This efficiency determines the economy of the whole scheme, yet it is a factor that is itself made up of several variable factors. For instance, with reversible pump-turbines, optimum efficiency for pumping is not attained at the same water-flow conditions as optimum efficiency for generating. Each operation has its own optimum conditions of head and water flow. But system operating conditions, coupled with the minute-by-minute variations in water levels in the two reservoirs, generally dictate that optimum efficiency in either mode is not achieved for more than a small percentage of the time, even when the machines have different speeds for pumping and for generating.

Changeover from pumping to generating or a start-up either to pump or to generate can usually be carried out very rapidly, and, as one system operator told us recently, this facility will be used to the utmost. In consequence, in the pumped-storage stations

of the future there may be a call for the universal use of automatic control coupled in many cases with starting-turbines or perhaps torque converters, all adding to capital cost.

We have drawn attention to these considerations not with any intention of decrying pumped storage but as a reminder that in this, as in any other engineering proposition, we must keep our feet on the ground. The case for pumped storage lies in achieving a favourable economic balance, and it is vital that in any given case this balance should be accurately and objectively assessed.

Indian Dam Rehabilitation Contracts

TWO years ago the Indian Branch of the Cementation Group of Companies secured a contract from the Tata Power Company for the grouting of the Walwhan dam. Seepage of water through this dam, which was built some 50 years ago and forms a part of the Tata Power Company's hydro-electric power-supply system, was a cause of concern and the Cementation Company guaranteed to reduce the leakage by 90%. This contract, valued at approximately £100,000, was satisfactorily completed at the end of February this year.

In April last, negotiations for a contract for the execution of the remainder of the remedial works on the Walwhan dam were brought to a satisfactory conclusion. This calls for the strengthening of the dam by means of the Coyne method, introduced by the Cementation Company into India eight years ago in the strengthening of the Tansa dam. The Cementation Company were also entrusted with the work of the grouting of the Shirawta dam which, as Walwhan dam, forms a part of the Tata hydro-electric power supply system.

The total value of this additional work is approximately £400,000 and it is planned for completion within the next two years.

Power Loan in Peru

A LOAN equivalent to $24 million for the expansion of electric power supplies in the area of Lima, is being made by the World Bank to the Lima Light and Power Company (Empresas Electricas Asociadas). The loan will help to finance two separate but related projects: the Marcapomacocha scheme to divert waters from lakes and rivers on the eastern slope of the Andes to the Santa Eulalia River basin in the west to provide more water for hydro-electric power development; and the construction of a power plant at Huinco on the Santa Eulalia to be installed initially with a capacity of 120 MW. The new power facilities will increase by 70% the power now available in Lima, the administrative, commercial and industrial centre of Peru.

The main works to be undertaken in the first stage of the Marcapomacocha diversion scheme consist of structures to collect the water of the Marcapomacocha basin on the eastern slopes of the Andes and a six-mile diversion tunnel through the mountain range to bring these waters to the Santa Eulalia basin on the western side. Increased water supplies from this source will not only provide water for the new power plant to be built at Huinco but will increase the production capacity of existing power plants downstream and provide more drinking water for Lima.

The electric power development consists of the construction of a concrete arch dam at Sheque, where two tributaries meet to form the Santa Eulalia River, and a pressure tunnel eight miles long from the dam to the site of the underground power house at Huinco, about 40 miles north-east of Lima. The power house will be built to accomodate four generating units of which two, with a combined capacity of 120 MW, will be installed initially. Transmission lines will also be built to connect the Huinco power plant with Lima.

Transmission Line Laid in Snowfield

A UNIQUE method of laying a temporary transmission line is being used in the Perisher Valley, Australia, where the heaviest snowfall for the time of year since 1910 recently interrupted work on a permanent line to Guthega power station. The contractors, Dulmison (Australia) Pty. Ltd., Sydney, are laying the temporary line on the snow in a series of S loops, stamping it into the surface, and passing current through it at 11 kV, generating sufficient heat for the cable to melt its way through the snow to the ground below.

Loch Awe Contract

THE North of Scotland Hydro-Electric Board have awarded a further contract to the Mitchell Construction Co. Ltd., of Peterborough and London, in connection with the Loch Awe project. The new contract involves the construction of foundations, roof, tailrace, transformer compound and other works for the Inverawe power station. In April Mitchells were awarded a contract for the construction of a barrage, intake, small power station and other works.

Turbines for Trinity, California

THE U.S. Department of the Interior has awarded the English Electric Export & Trading Co. Ltd. a contract for two 85,000 h.p. Francis water turbines. The contract is worth some £275,000 ($832,830). The turbines are for the Bureau of Reclamation's Trinity power plant, near Lewiston, California. The turbines will be a special design having two interchangeable runners, one of which will operate at a 426 ft. head with an output of 85,000 h.p. and the other at 334 ft. head with an output of 70,000 h.p. This arrangement has been specified because of the considerable seasonal changes in the level of the water in the station's storage reservoir.

Pamba and Perambikulam Projects

CONSTRUCTION is expected to commence soon on the Pamba hydro-electric project, one of the major schemes in Kerala State, when the Planning Commission of India grants it its approval. The scheme, which is estimated to cost Rs. 255 million, will have an installed capacity of 300 MW and will also bring irrigation facilities to about 150,000 acres of land in the Pamba valley. The project is expected to be inaugurated in the autumn of this year, and should be completed by 1965.

Agreement has been reached between the governments of Kerala and Madras on the sharing of the Perambikulam river water in connection with the Perambikulam multi-purpose project. This project

considers the diversion of a few west-flowing rivers having their sources and catchments in Madras and which run to waste into the Arabian Sea at present. The plan is to build a series of dams and the collected water is to be diverted via a tunnel to irrigate some 250,000 acres of land and to generate 100 MW of electricity. The cost of this project is estimated at over Rs. 300 million.

New Process for Aluminium

ALUMINIUM LIMITED has approved the construction of new facilities at Arvida, Quebec, for the production of aluminium by a basically new process. This process has been under development for some years through the laboratory and pilot-plant stages. It employs, as its principal raw material, bauxite of roughly similar grades to that required by the conventional means for the production of commercial aluminium. It does not, however, appreciably reduce the large power requirement which is an outstanding characteristic of the conventional process, but gives promise of substantial savings in other elements of production cost and in the investment required per ton of capacity.

The new facilities, designed as an experimental unit, will have a capacity of 6,000 to 8,000 tons of aluminium per year. They will be operated primarily for the purpose of confirming the conclusions already reached concerning the costs obtainable. It is expected that the new facilities will be available within two years. Their capital cost will be of the order of $4,000,000. The process is covered in a large number of countries by patents held by Aluminium Limited.

Mettur Tunnel Hydro Scheme

PRELIMINARY work has been started on the Mettur tunnel hydro-electric scheme and the authorities are now awaiting a Russian offer for the supply of plant and equipment on a long-term basis. Four experts, including the vice-president of Machinoexport, Moscow, have already visited the site and have studied details of the scheme. The initial stages of the scheme envisage the utilisation of 10,000 cusecs of discharge from the Mettur reservoir by installing two generating units of 50 MW capacity each.

Power Scheme for Nyasaland

NYASALAND is to get a new hydro-electric power scheme which at one stroke will achieve two major objectives of vital importance to the country's future. These are the production of hydro-electric power from the Shire River, and the stabilising of the level of Lake Nyasa. The Minister of Economic Affairs, Mr. J. M. Caldicott, told the Federal Assembly recently that the Government is to vote £100,000 on preliminary preparations for the Nkula Falls scheme —mainly working drawings and contract documents. The scheme will cost only £3,000,000 which the Government believes will be raised without difficulty. The first practical steps were taken in 1951, when the Nyasaland Government commissioned Sir William Halcrow and Partners to make the Shire Valley survey, which entailed a study of the river, the lake level, power transport on the lake, communications and navigation, and land reclamation. Hydro-electric power stations on the river were proposed in the report, summarised in our September 1955 issue, which followed the survey. But the plans envisaged were beyond Nyasaland's resources at that time. Now the Nkula Falls scheme has been decided on, as a modest foundation on which a big scheme can eventually be built.

The Nkula Falls are on the Shire River, 22 miles north-west of Blantyre, and consist of rapids falling 170 ft. in a horseshoe bend. Under the scheme the bend will be cut off by a tunnel, at the bottom of which the power station will be built. But first, the flow of the river must be regulated. This will be done by building across it a 14-gate barrage at Liwonde, on which a road will be built, replacing the present pontoon ferry. It will be possible ultimately to put on the same site a fairly low dam, giving a 40 ft. head, build a second tunnel and raise the supply to 134 MW.

Accompanying the Nkula Falls scheme is a companion scheme to improve the Blantyre-Limbe town water supply, now very inadequate, by pumping water from the vicinity of the power station, using the power supplied by the station. Work on the Nkula Falls scheme is likely to start about March, 1961, and will take nearly three years to complete.

N.Z. South Island Grid

THE first 220 kV twin-conductor transmission line in New Zealand is now about two-thirds completed between Benmore and Islington in the South Island and is expected to be in commission early in 1962, when it will carry the power from Roxburgh's four new generators. When Benmore is brought into commission in 1965, the connection to Benmore will be completed and the line will ultimately link up all the projected stations on the Waitaki.

Swedish Order for Oahe Dam

THE Swedish electrical manufacturers, ASEA, have received a large order from the U.S. Army Corps of Engineers, Omaha, for a 103,000 kVA three-phase transformer for 115 kV and nine 68,700 kVA single-phase transformers for 230 kV. The transformers are intended for a large hydro-electric power station by the Oahe dam on the Missouri river in the State of South Dakota. As is usual in the U.S.A., the delivery time is rather short, and the shipment of the first units is to commence in the middle of 1961 and is to be completed a year later. The order is worth about a million dollars.

Volta River Project Assured

ACCORDING to a recent announcement by the Ghana Government the financing of the Volta River project is now assured. It is understood that the World Bank has promised a loan of $40 million, the United States Government $30 million, and the British Government $14 million (£5 million), these promises to take effect when a satisfactory agreement has been concluded with the Volta Aluminium Company. These loans, totalling $84 million, will be matched by an equal sum to be provided by Ghana.

The first suggestion for an integrated scheme on the Volta was made in 1915 by Mr. A. E. Kitson, and in 1949 the Gold Coast Government engaged Sir

William Halcrow and Partners as Consulting Engineers. A Government White Paper was issued in 1952 (see WATER POWER, January 1953) and on the advice of the Consulting Engineers a Preparatory Commission was set up in 1953. In 1956 a full report was published by H.M. Government, which was summarised in an article in our October 1956 issue. In the autumn of 1958 the Henry J. Kaiser Company sent a technical team to Ghana, who reported favourably in 1959 (see WATER POWER, June 1959).

Dams on the Papaloapan

ACCORDING to the Banco Nacional de Comercio Exterior, the Mexican Federal Electricity Commission is planning to construct eight more dams along the Papaloapan River to enable the hydro-electric systems in the area to expand their capacity to 660 MW.

Details on the new dams are as follows: together with the already functioning President Aleman dam, the Cerro de Oro will form a single basin having a storage capacity of 10,500 million cu. m. Three others will carry the names Cerro Frio, Felix Vazquez, and San Cristobal; and the four remaining projects will be located along the tributaries of the San Juan Evangelista River.

The Cerro de Oro dam will bring about a 75% increase in electric power production at the Temazcal plant, and the San Cristobal dam will provide seven auxiliary irrigation systems for the cultivation areas at Valle Nacional and Chiltepec. For their part, the Cerro Frio and Felix Vazquez dams will furnish irrigation for a minimum of 300,000 hectares and produce 210 million kWh yearly. The Chiltepec dam will be able to generate 60 million kWh per year, and the dams along the San Juan Evangelista River, 185 million kWh.

Sweden's Power Projects

WATER power is likely to remain Sweden's primary source of power for several decades to come, according to a forecast made by the Swedish State Power Board. Calculations foresee an economically remunerative exploitation of Sweden's water power of up to 80,000 GWh, out of which 43,000 GWh would be produced from State-owned property. The present annual capacity of production from this source is 21,000 GWh. The remaining State-owned reserves are considered to be comparatively inexpensive to build and will probably have been fully utilised by the end of the present decade.

Nuclear, steam and gas-turbine power will probably be resorted to, however, to an increasing degree in the 1970's. By that time the cost of establishing nuclear power plants is expected to decrease, whereas building the remaining hydro-electric reserves will become successively more expensive.

Commonwealth's Highest-Head Turbines

BOVING & CO. Ltd. have secured a contract to supply a fifth 82,500 h.p. Pelton turbine for Poatina power station, the first underground power station in Tasmania and part of the Great Lake power development scheme. The Hydro-Electric Commission of Tasmania have already ordered four Boving turbines for this station, and these are now in course of manufacture, together with the turbine inlet valves and six 36 in. pipeline isolating valves, all of the Boving rotary type. The maximum operating head for the Poatina turbines will be 2,720 ft., which is believed to be the highest for any hydro-electric scheme in the Commonwealth and for any turbine yet designed in Britain.

The station will be situated below the Great Western Tiers, and will use water from the Great Lake and from Arthur Lakes, in Central Tasmania. It is expected that the first set, consisting of a 62,500 kVA generator and turbine, will be commissioned in 1964.

Electronic Control of Power

THE first step has been taken towards complete electronic control of power supplies between the Snowy Mountains hydro-electric project and the States of New South Wales and Victoria. The N.S.W. Electricity Commission has installed some very modern power station equipment to decide and arrange the most economic use of the State's power plants to meet fluctuating demands. Similar systems are to be installed in Victoria and by the Snowy Mountains Authority. The N.S.W. equipment was imported from the U.S.A. at a cost of about £A130,000. It consists of electronic units at eight power stations, all controlled by a master unit in Sydney.

Aratiatia Hydro Station

A START on diverting the Waikato River at the Aratiatia Rapids through a diversion channel has been made in preparation for the construction of the Aratiatia hydro-electric scheme. At first the river will pass down both its present course and the diversion channel but the full flow will be diverted down the new channel. Construction of a new cofferdam across the head of the rapids began in August. The station is to have a generating capacity of 90 MW, 30 MW more than was originally proposed, and first power is expected in the winter of 1964.

Work at Kariba Enters Second Phase

THE Rhodesian Company of the Cementation Group is now engaged in driving a complex of tunnels through the hill on the north bank in connection with the exploratory work for the second phase of the Kariba power scheme. Drilling and blasting operations are in progress, and thorough tests are being made of the rock that will be excavated for the second power house, which will be some 50% larger than the existing power house. Cementation's preliminary work is expected to be completed early in 1961, and construction of the north-bank power house should begin in earnest the following year.

Sixth World Power Conference

THIS conference—mentioned in WATER POWER, August 1960, page 292—will be held in Melbourne, Australia, in October 1962, and United Kingdom participants should note that they can obtain full information at any time from the Secretariat of the British National Committee of the World Power Conference, 201–2 Grand Buildings, Trafalgar Square, London, W.C.2. Participants from other member countries of the World Power Conference may obtain information from their local National Committees.

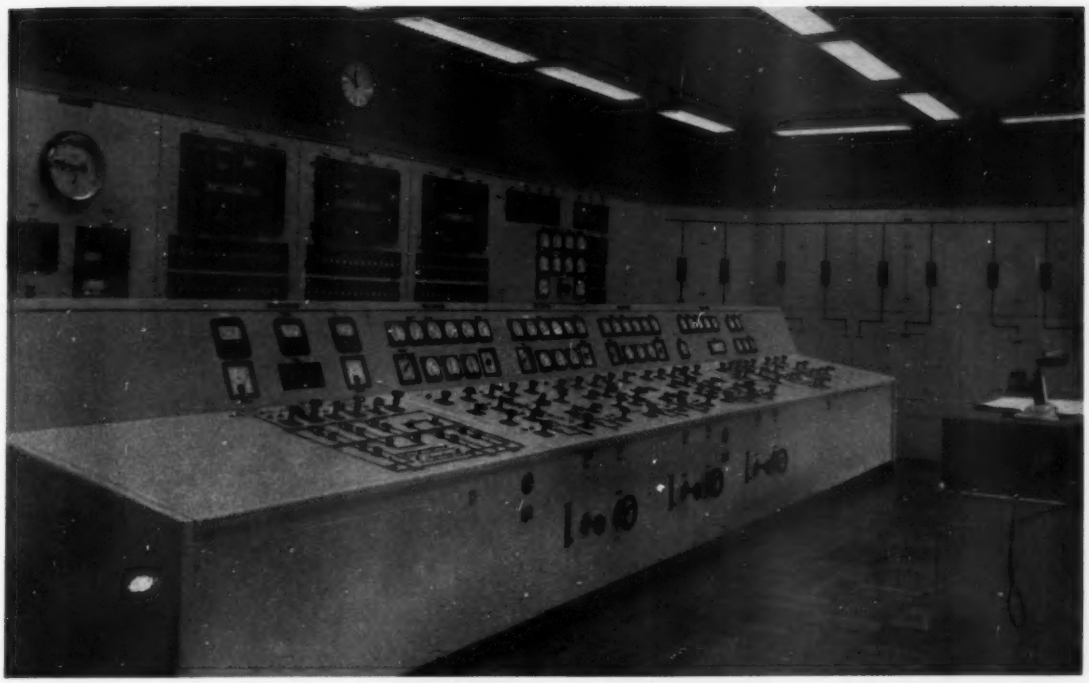


Fig. 1. A view of the Cipreses power plant control room

The Power Situation in Chile

This article presents a picture of the present power situation in Chile and outlines the overall plan for development up to 1972, with special reference to the work of ENDESA

By RENATO E. SALAZAR* and ALBERTO BENNETT†

CONVENTIONAL fuels are expensive in Chile. The main coal deposits, which are located south of the city of Concepción, lie several thousand feet below sea level and several miles from the coast. Transportation and ventilation within the mines are consequently difficult and the extraction of coal costly. On the other hand, Chile is not yet self-sufficient in oil products and for years to come it will have to import a large proportion of its requirements. Import duties on oil products are so regulated that domestic coal can compete in the internal market. As a result, it is not at all remarkable that for many years Chile has looked upon hydro resources as its main source of electricity, at least where water is available.

Chile has a continental area of 290,000 sq. miles, of which 160,000 are barren and unfit for agricultural production; it is a narrow strip of land with 2,600 miles of coast along the Pacific side of South America. With a population of 7·34 million inhabitants, it has the highest electric power generation *per capita* in Latin America—600 kWh per year‡.

From the point of view of hydro-electric resources, the country can be divided into three zones, as indicated in Fig. 3. The Northern Zone, which lies north of Lat. 27°, is a desert where the main nitrate, copper and other mineral deposits are located. Hydro-electric resources are almost non-existent and limited to the area of the high Andes since the water infiltrates or evaporates on its way towards the Pacific Ocean. Each mining industry has its own electrical generating facilities, essentially isolated from each other, and power is generated by steam or diesel plants burning imported fuel oil. The Central Zone is located between Lat. 27° and 42°. As the administrative, industrial and agricultural centres are situated there, it is the country's most densely populated area. There are abundant hydro-electric resources, increasing from the north towards the south. The total yearly precipitation in the Andes ranges from 15 in. at Lat. 27° to 150 in. at Lat. 42°.

The Southern Zone, which is located south of Lat. 42°, is unpopulated, with heavy precipitation all the

* Head of the Engineering Department of ENDESA
† Member of staff of the Engineering Department of ENDESA
‡ As Chile neither imports nor exports electric power, this figure gives a close idea of consumption *per capita* (about 15% lower).

Fig. 2. A general view of the Cipreses power plant

TABLE I.—HYDRO-ELECTRIC RESOURCES, ELECTRIC GENERATING CAPACITY AND PRODUCTION IN CHILE, BY ZONES (1959)

	Northern Zone	Central Zone	Southern Zone	Total
Potential hydro power (MW at average flow) ...	50	9,220	11,030	20,300
Generating capacity, MW				
Hydro	7	583	1	591
Non-hydro	264	221	14	499
Total	271	804	15	1.090
Production, GWh				
Hydro	22*	2,899	1	2.922
Non-hydro	1,250*	197	26	1.473
Total	1,272	3,096	27	4,395
Population				
Thousands of inhabitants	380	6,778	227	7,385

* Estimated.

year round. The Andes mountains, which run parallel to the coast at some distance from it in the other zones, here form a coastal range partially submerged in the Pacific in a complicated formation of thousands of islands. Here, huge hydro-electric possibilities can be developed as, for example, in Norway. In the southern extreme of this zone are oil and gas fields and large coal deposits. Table I gives some of the pertinent information on these zones.

Work Done

Up to 1939 the most important hydro-electric developments consisted of several plants located around the city of Santiago in the Central Zone. Plants owned by concessionaires of the Electric Public Service of this area with a capacity of 150 MW were operating at that date. In 1939 the Chilean Government created the Corporación de Fomento de la Producción (National Development Corporation) as an agency of the Government for the planning, promotion and financing of new industries. Electricity supply, being fundamental to any industrial expansion, received special consideration from the Corporación de Fomento and a subsidiary for such a purpose was created. Later, in 1943, it became a separate corporation named the Empresa Nacional de Electricidad S.A. (ENDESA).

The Corporación de Fomento and ENDESA started with a systematic evaluation of the power potential of the country and a survey of its requirements. The fact that the Andes mountains stretch parallel to the coast and not far from it, provides excellent possibilities for hydro-electric developments where water is available. Several projects were started, taking account of the priorities determined by the electric load. All these projects are located in the Central Zone. There the rivers run from east to west, their courses cut through narrow canyons and high slopes, and diversions, by means of tunnels or canals, provide high heads for reasonable-cost hydro-electric power schemes. Table II shows the hydro-electric generating capacity operating in Chile in 1959.

At present 85% of this generating capacity operates in the

interconnected system in the Central Zone of Chile at a frequency of 50 c.p.s., and 9% operates independently at a frequency of 60 c.p.s. The 50 c.p.s. frequency has been declared standard for the whole country.

In Fig. 5 we show the monthly average flow (in arbitrary units) for several rivers from north to south of the Central Zone. In the northern part of this zone rivers are of glacial hydrological regime with small flow in the winter months and high flow in spring and summer. This characteristic gradually changes towards the south where the regimes of rivers become pluvial with high flow in winter and low flow in summer or autumn. It can be seen from this graph that some sort of complementary pattern exists in the river flows, and this fact has been taken into account in the hydro-electric planning by:—

(a) wherever possible using natural lakes, as regulating reservoirs (artificial reservoirs with dams are expensive and technically difficult because of the steep slope and high sediment content of the rivers), and,

(b) having an effective electrical interconnection between the southern and northern plants.

The sequence in which these schemes were put into operation was based on minimising the transmission cost, so that originally most of the plants supplied isolated areas.

The distance between generating plants and load centres called for a carefully planned transmission system since this has an important bearing on the total cost per kilowatt. Wherever possible, ENDESA has followed a rigid standardisation of transmission and distribution voltages. These are 13·2 kV for urban and rural distribution, 23 kV for distribution in areas where loads are larger and widespread (mining districts or others of that sort) and 66 kV and 154 kV for transmission circuits. In many cases the voltages adopted by ENDESA have been followed by other companies; such is the case with several 13·2 kV and 66 kV lines.

Table III gives some characteristics of ENDESA's hydro schemes now in operation or planned up to 1972.

With the exception of Antofagasta, all of ENDESA's hydro stations in operation up to 1959 were built in areas far from centres of population, thus requiring the construction of new roads, housing schemes, water and fuel supply as well as temporary electrical generating and communication facilities. This factor

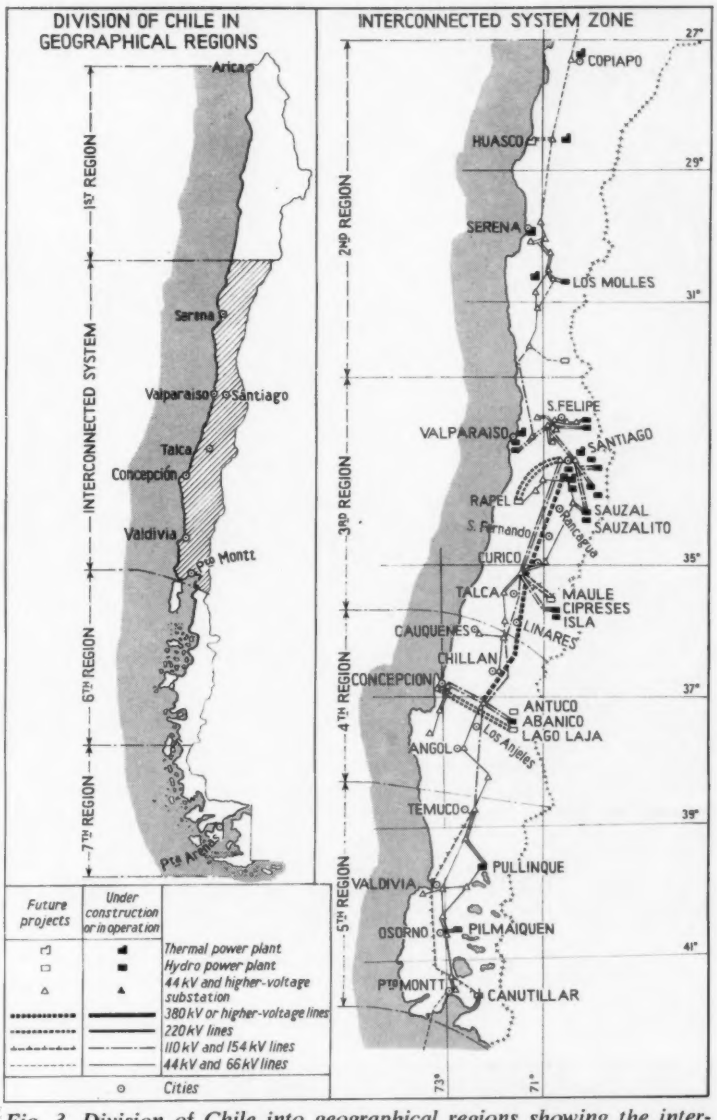


Fig. 3. Division of Chile into geographical regions showing the interconnected system zone

TABLE II.—HYDRO-ELECTRIC POWER PLANTS OPERATING IN CHILE IN 1959

	Total installed capacity
Industries, self suppliers	MW
Cement	18
Copper	57
Paper	25
Others	8
Public utilities	
C.C.E.*	89
ENDESA	373
Others	21
Total	591

* Compañia Chilena de Electricidad Ltda., a subsidiary of the "American & Foreign Power Co." of U.S.A.

is reflected in the investment cost per kW, which is considerably higher than in works planned for the period 1959–1972, where the new plants will be near to the existing ones and will thus utilise a great part of the facilities already mentioned.

Among the stations in operation in 1959, Los Molles particularly calls for attention. Having two 8 MW units and a gross head of 1,183 m., it is the highest-head plant of the Western Hemisphere and has been operating successfully since 1952. This plant is located about 300 km. north of Santiago in an intermediate area between the arid Northern and the Central Zone. In this area the most economical source of electric supply is a combination of high hydro and diesel or steam power, so that during the dry periods the non-hydro plants supply the base load and the hydro ones, with storage capacity, the peaks.

Future Developments

Within the period 1959–1972 some larger hydro-electric schemes are contemplated, as shown in Table III. Among them, Rapel with an initial capacity of 280 MW and final capacity of 350 MW, Maule with 240 MW, and Lago Laja with 250 MW, are the most important.

It is expected that the installation cost per kW of these schemes will be considerably lower than schemes now in operation; this is in part due to the larger generating capacity to be installed at each site and in part to the factors already mentioned with regard to the roads and other facilities in the area where the plants will be located. Some important savings can be predicted for the transmission system as some of the existing capacity will be utilised or some of the present substations will be expanded at a lower incremental cost.

The seasonal and daily regulating capacity will be concentrated in Rapel, Lago Laja or Pullinque.

Besides these plants, during the period under consideration ENDESA contemplates the installation of a high-head plant for the Arica zone near Chile's northern border and two small plants, such as those at Piruquina and Puerto Aysén, for use in the Southern Zone.

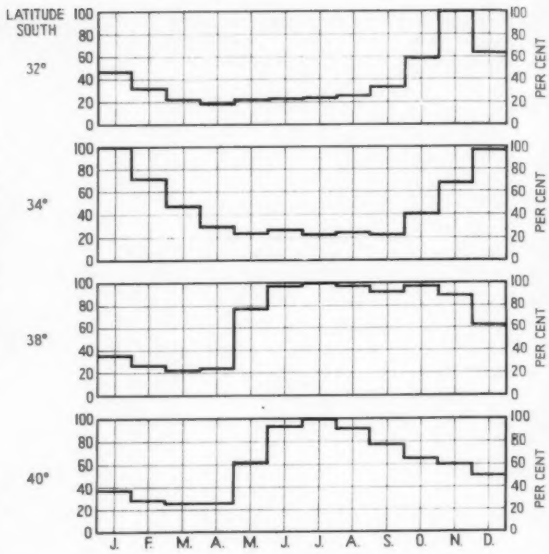


Fig. 5. Monthly average flow in percentage of maximum

In 1972 it is expected that the electrically interconnected area of Chile will extend from Lat. 26° to Lat. 43° (about 1,200 miles) and large quantities of energy will be transferred from south to north, although, by the schedule of installation of new generating stations, a substantial proportion of energy generated will be consumed in the vicinity of each plant. This scheme will allow the run-of-river type of plant to generate the maximum energy available, and the large storage type, such as Rapel and Lago Laja, to supply the seasonal power deficits. Within the period 1959–1972, transmission voltages of 220 and 400 kV are contemplated.

It is possible to predict that after 1972 great emphasis will be given to the construction of large storage-type plants which can be developed favourably in the Bío Bío River, around Lat. 38°.

The above plan does not contemplate large hydro-electric developments in the Southern Zone, where, as has been mentioned, enormous hydro-electric reserves can be economically developed. A preliminary survey of some sites shows that electric energy can be produced at an average price of around U.S.$4\frac{1}{2}$ mills per kWh, or even less, which would be suitable for the establishment of electro-chemical and electro-metallurgical industries. But these developments can only materialise if large industries are created independently by companies working in such fields.

The entire interconnected scheme will be supported by a number of steam stations of which, by 1972, 30 MW will be located at Huasco (Lat 28° 30′), about 250 MW around Santiago, and about 50 MW around Concepción. With the exception of Huasco, these steam stations are or will be installed by other companies.

Fig. 4. Tunnel work at Pullinque power plant under construction

Design, Construction and Operation

ENDESA has its own engineering and construction forces. The large scope of the plan justified this decision because of the highly specialised type of work required —earth dams, tunnels (some in fractured rock conditions), canals, intakes and sand-traps for small and medium flows as compared with the general engineering of the country.

Experience has been gained on earthquake-proof designs. Seismic and erosion problems have led to emphasis being placed on tunnels rather than the open canals as used in the old plants. The relatively new geological formation of the Andes mountains requires careful field studies such as extensive use of drilling or reconnaissance galleries for tunnel design to deal with faulty areas. The problem of waterproofing natural dams resulting from volcanic eruptions has been under consideration at two sites and will be discussed in a future article in more detail.

Steel structures for transmission lines and substations as well as some less-complicated gates, cranes, and other structures, distribution transformers and switchgear are designed by ENDESA and manufactured in the country. The main proportion of the equipment required for generating stations and transmission systems is

Fig. 6. A general view of the Los Molles power plant

TABLE III.—HYDRO-ELECTRIC SCHEMES COMPLETED OR PLANNED UP TO 1972

Name	Lat.	Capacity	Gross head	Average annual production	Regulation	Investment cost (1)
In operation 1959		MW	m.	GWh	$m.^3 \times 10^3$	U.S.$/kW
Antofagasta	23° 30′	1 5	430	10	—	— (2)
Los Molles	30° 30′	16	1,183	57	17	420
Sauzal	34°	77	120	450	450	390
Sauzalito	34°	9	25	58	—	
Cipreses	36°	101	342	590 (3)	170,000	370
Abanico	37° 30′	135	147	683	—	340
Pilmaiquén	40° 30′	35	33	252	500	300
Planned (1959–1972)						
Lauca	18°	8	1,000	80	—	390
Rapel	34°	280 (4)	81–69	825	430,000	200 (4)
Isla	36°	68	98	450	—	265
Maule	36°	240	320	1,650	500	280
Lago Laja	37° 30′	250	368–300	705	5,000,000	—
Antuco	37° 30′	195	180	1,255	—	—
Pullinque	39° 30′	49	49	268	230,000	345
Canutillar	41° 30′	75 (5)	225	650	—	300 (5)
Piruquina	42° 30′	4	23–18	33	—	>400
Puerto Aysén ...	45° 30′	4	100	33	—	420

(1) Includes the transmission system up to the capacity of the generating station. Does not include customs duties paid on imported equipment.
(2) Utilises water-supply installations.
(3) Assuming a 50% seepage reduction of La Invernada Lake.
(4) Includes civil works for a final capacity of 350 MW.
(5) Includes civil works for a final capacity of 150 MW.

imported, but the selection is made, within the world market, by separate items. The overall co-ordination schemes for proper operation of the equipment from different suppliers are made on ENDESA's drafting boards. Examples of this policy are the panel board and desk of the Cipreses power-plant control room which has been in operation since 1955, shown in Fig. 1; there, on metal assemblies locally designed and manufactured, we find relays, instruments, switches, etc., from a dozen different manufacturers and everything works satisfactorily!

Owing to this rather unusual practice of concentrating in one body the responsibilities of design, construction and operation of electric power generation, ENDESA has been able to exchange experience in the three phases of the business with great advantage to personnel training, emphasising the local conditions of the country in the problems of electricity supply as a whole. This task would have been more difficult if we had been unable to receive the generous help and co-operation of foreign institutions for the training of engineers, as well as financial assistance by means of long-term loans for the foreign currency requirements.

Increasing Effort in Hydraulics Research

The Hydraulics Research Station, D.S.I.R., at Wallingford, is being enlarged to accommodate an expanding programme of research. The extensions include an enlarged main hall which will contain a wave basin 270 ft. in length. The report* of the Director, F. H. Allen, M.A., M.A.I., M.I.C.E., describes the basic researches carried out, the advances made in technique, and details of practical investigations into hydraulic problems in many parts of the world. An interesting technique developed at the station is a method devised for measuring, by means of fluorescent tracers, the rate at which pebbles or sand drift along the coastline—a knowledge of this rate of drift being of importance to the coastal engineer, who has hitherto had no satisfactory method available for determining it.

Three forms of bellmouth spillway for Tryweryn reservoir, Bala, North Wales, were tested and a modified design has been recommended. Work is also in hand on the Ffestiniog pumped-storage scheme for the Central Electricity Generating Board where work is being carried out and for which a new model to a scale of 1/30 has been constructed. Closed swirls were frequently in evidence for short periods at each pump intake but in no circumstances did open vortices form, and as the swirls were unstable, it was concluded that the conditions in the prototype would be satisfactory. This model was also used to make a detailed examination of the flow conditions at the intake screen to enable the wide horizontal support bars to be tilted so as to create as little interference to the flow as possible.

Other researches described refer to thermal-station matters, docks, channel improvements at Burton-on-Trent, the Mersey estuary, the Severn estuary and other investigations that have little relation to the hydro-electric engineer.

Rectifiers and Transformers for India. An order worth about £500,000 for rectifiers and transformers for Hindustan Aluminium Corporation has been awarded to The English Electric Co. Ltd. for a new aluminium smelter in Uttar Pradesh State. Power will be derived from the Rihand power station, for which English Electric has supplied five 77,000 h.p. water turbines. The main transformers will consist of two 60 MVA 132/11 KV units and two 56 MVA 11 KV regulating units, and each of the six rectifier equipments will comprise a transformer and a group of air-cooled sealed steel-tank mercury-arc rectifiers. Each group of rectifiers will be rated at 10,000 A 750 V d.c. The total load capacity will be 45 MW. The contract also includes control gear, d.c. switchgear and auxiliaries. Consultants for the plant are Kaiser Engineers of Oakland, California.

Production and Distribution of Reactive Energy. The Swedish State Power Board's publication, Blue and White Series 27, gives an account of the most economic means of producing and distributing reactive energy with particular reference to shunt and series capacitors. A detailed discussion shows the power losses in the capacitors and general costs for different connections for a desired reactive phase compensation on a distribution network.

The publication concludes that to obtain economic phase compensation, and thus a decrease in power losses, shunt capacitors are most suitable and that they ought to be installed in the distribution network. But to improve voltage regulation, series capacitors offer the best advantages. Synchronous condensers should be used to produce reactive power as a supplement to power transmission on a high voltage system so as to permit optimum design with regard to losses, series compensation, transmission capacity and stability.

Kariba. The Federal Power Board of Rhodesia and Nyasaland have sent us a handsome brochure entitled "The Opening of Kariba" which gives a brief account of the plant. When completed this will provide a total capacity in excess of two million horsepower and supply much-needed additional power to the copper belt of Northern Rhodesia.

The provision of housing and the establishment of a township with an electrical supply, a swimming pool, schools, a hospital and many other buildings were major undertakings, for at the peak of employment some 7,000 Africans and 1,500 Europeans were engaged on the contract. An account is given of the dam and the lake, the underground power station, the transmission system, and of the costs of the scheme.

Kariba power is produced more cheaply than power from new thermal stations; for instance, it is estimated that during the 10-year period 1960–1970 the cost of producing power from Kariba would be some £44 million less than the cost of continuing to produce power from coal-fired stations and that at the end of the period the difference in favour of Kariba would be running at nearly £10 million per annum.

* "Hydraulics Research, 1959." Report of the Hydraulics Research Board with the Report of the Director of Hydraulics Research. Published for the D.S.I.R. by Her Majesty's Stationery Office. Price 5s. 6d., by post 5s. 11d.; U.S.A. 99 cents.

Water Turbines and Dimensional Analysis

The authors outline a non-dimensional approach to the preliminary design of water turbines and employ charts based on an extensive study of current practice

By RAMADAN SADEK, M.Eng., D.I.C., Ph.D. (Lond.), A.M.I.Mech.E.* and MOHAMED ATAFY SINBEL, D.I.C., Ph.D.(Lond.)†

WATER-TURBINE designers are to some extent reluctant to make full use of a non-dimensional approach in their preliminary estimates, but such an approach can be of value with regard to these estimates, as well as being of help in establishing a globular survey of losses and of efficiencies. Nag, Madhaven and Zanobetti have contributed to that end in their articles in WATER POWER.‡

For preliminary estimates one can subdivide the problem into two main sections: (i) the approach and exit passages; (ii) the turbine proper. These two are so interrelated that neither can be approached without proper concern for the other.

The first matter to be decided by the designer is the type of turbine to suit the prevailing conditions, and the first important grading scale is that which groups the duty variables (output, effective head and speed), to form the parameter known as specific speed.

Metric specific speed $= N_s = \dfrac{N\sqrt{\text{h.p.}}}{H^{1\cdot25}}$ ... (1)

where:

N = operating speed in revolutions per minute,
h.p. = turbine output in horsepower,
H = effective head in metres of water.

Obviously specific speed as defined above is a dimensional parameter which depends on the system of units used, and the following expresses the relation between specific speed in the different unit systems (Fig. 2).

$N_s(\text{m. h.p.}) = 4\cdot4\ N_s(\text{ft. h.p.}) = 1\cdot17\ N_s(\text{m. kW})$ ... (2)

Duty variables, however, can be grouped to form a non-dimensional parameter or "shape number" n_s:

$$n_s = \rho^{\frac{1}{2}} \frac{n\sqrt{(\text{k h.p.})}}{(\rho g H)^{1\cdot25}}$$
$$= 0\cdot824 \times 10^{-3} N_s(\text{m. h.p.})$$
$$= 0\cdot367 \times 10^{-2} N_s(\text{ft. h.p.}) \quad \text{... (3)}$$

where:

ρ = water density,
k = constant to convert horsepower to the appropriate units,
n = turbine speed in revolutions per second.

A statistical study of existing plants shows a distinct relation between the operating head and the specific speed of the selected units, and Creager and Justin recommend the following empirical formulae for estimating the suitable specific speed for a given operating head:

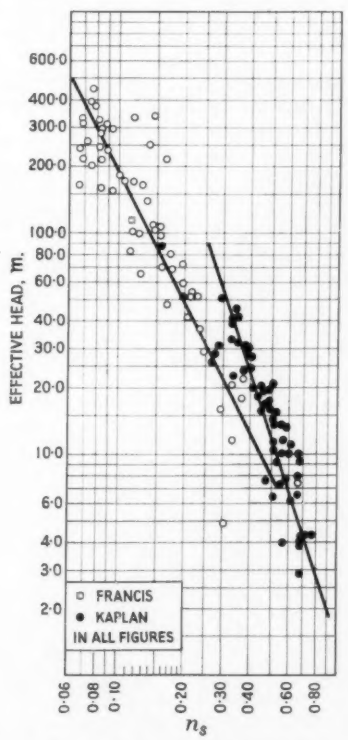


Fig. 1. Current practice for shape number as a function of operating head

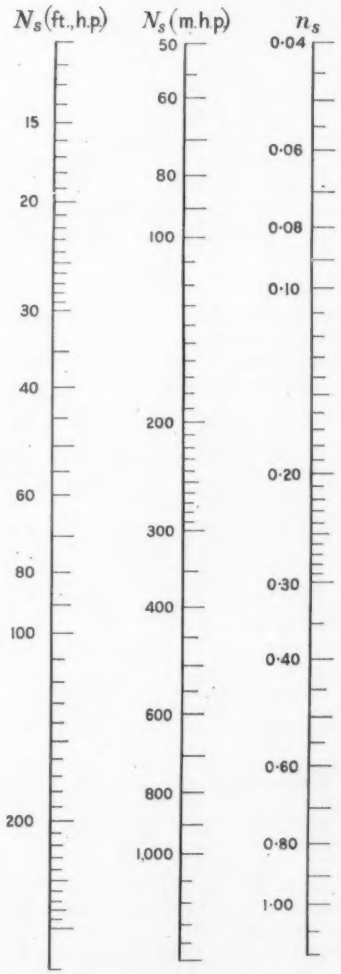
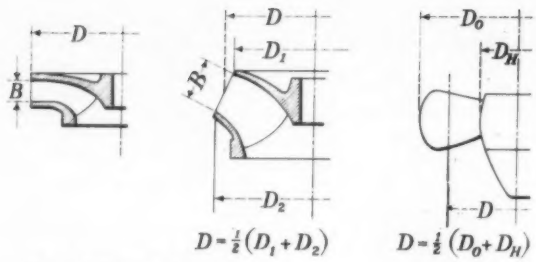
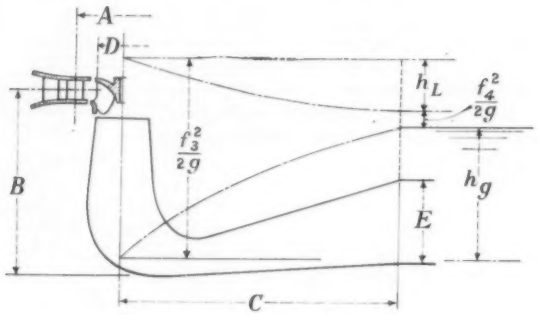


Fig. 2. Shape-number and specific-speeds conversion diagram

* Professor, Head of Mechanical Department, Assiut University.
† Lecturer, Faculty of Engineering, Ein Shams University.
‡ All references are collected at the end of this article.



(a)



(b) $\frac{A}{D} = a_r$, $\frac{B}{D} = b_r$, $\frac{C}{D} = c_r$ AND $\frac{E}{D} = e_r$

Fig. 3a. Runner geometry
Fig. 3b. Turbine and draft-tube geometry

$$N_s(\text{m. h.p.}) = \frac{22200}{3{\cdot}28H + 32} + 83{\cdot}5$$

for Francis units ... (4)

$$N_s(\text{m. h.p.}) = \frac{30800}{3{\cdot}28H + 32} + 154$$

for Kaplan units ... (5)

In the present work a wide range of turbines of different makes was selected for study. The corresponding data, plotted in Fig. 1, emphasise the existence of such a relation. The following expressions give the average trend:

$N_s(\text{m. h.p.}) = 1750H^{-0{\cdot}51}$ for Francis units ... (6)
$N_s(\text{m. h.p.}) = 1377H^{-0{\cdot}33}$ for Kaplan units ... (7)

Table I gives the recommended specific speed for turbines operating at varying heads according to different practices:

TABLE 1. RECOMMENDED SPECIFIC SPEEDS

Turbine Type	Francis			Kaplan		
Effective head, m.	350	100	40	60	30	10
Creager & Justin	102	145	220	288	390	629
Morgan Smith	79	158	264		460	790
USSR	61	157	314	426	564	880
Zanobetti	85	160	260			
Equations 6 & 7	88	167	266	356	450	644

Once the specific speed is decided upon, the next step is to determine the main geometrical dimensions of the plant. For the present study, the reference unit length is taken arbitrarily as the mean diameter of the rotor as defined in Fig. 3*a*; all other dimensions are thus referred to it. Needless to say the geometry, the kinematics and dynamics of the flow, and consequently the efficiencies, are all functions of the shape number. Fig. 3*b* shows the main geometrical coefficients for the turbine proper and the draft tube.

In determining the speed and flow ratios it should be remembered that the head and discharge coefficients are known non-dimensional parameters relating the kinematics and the geometry of both the flow and the rotor. Thus these ratios are defined as:

$$\text{Speed ratio} = \phi = \frac{\pi DN}{60\sqrt{(2gH)}} \quad \ldots (8)$$

$$\text{Flow ratio} = \psi = \frac{Q}{\pi D^2 s\sqrt{(2gH)}} \quad \ldots (9)$$

where: Q = through flow

$$\text{Discharge coefficient} = C_Q = \frac{60Q}{ND^3} = \frac{\pi^2 s\psi}{\phi} = \pi^2 s\lambda \quad \ldots (10)$$

$$\text{Head coefficient} = C_H = \frac{gH}{n^2D^2} = \frac{\pi^2}{2\phi^2} \quad \ldots (11)$$

All these parameters are functions of the specific speed and consequently of the shape number; in fact the shape number can be put as an explicit function of these parameters in the following way:

$$n_s = 0{\cdot}995\,(C_Q\eta_0)^{\frac{1}{2}}C_H^{-0{\cdot}75} = 0{\cdot}397\,\eta_0^{\frac{1}{2}}(s\lambda)^{-0{\cdot}75} \quad \ldots (12)$$

where η_0 = the turbine overall efficiency defined as the ratio of the output shaft horsepower to the input water horsepower.

Figs. 4, 5, 6 and 7 show the average trend of present practice for these four main parameters (ψ, ϕ, C_Q and C_H) at varying shape numbers. After deciding on the shape number for the unit suiting the prevailing con-

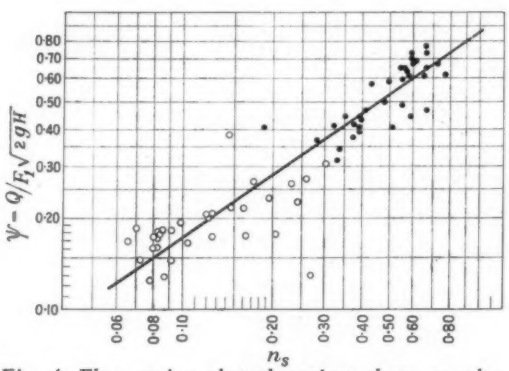


Fig. 4. Flow ratios plotted against shape number

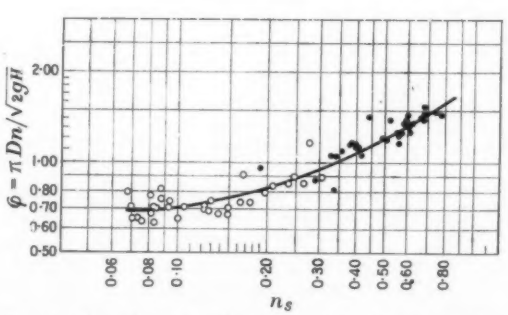


Fig. 5. Speed ratios plotted against shape number

ditions the nomogram given in Fig. 8 may now be used for estimating the main dimensions for the selected unit, with the help of the charts given in Figs. 9, 10, 11, 12, 13 and 14.

Kinematics of the Flow

In water turbines, as in all other rotodynamic machines, energy exchange between the flowing water and the turbine rotating element is effected by two main flow phases: the first is mainly concerned with the fluid mass flow through the machine, while the second concerns energy transfer between the flowing water and the rotor blades. Energy transfer is carried out through changes in the angular momentum of the through flow. Generally speaking, either part or the whole of the available water energy is converted into kinetic energy before undergoing energy exchange in the rotor passages.

The kinematic history of the flowing water, from the moment it enters the turbine proper till finally it is ejected through the draft-tube exit area, can be classified as:

i. Accelerating the flow to impose upon it angular momentum prior to entering the rotor.

ii. Energy exchange between the flowing water and the rotor blades.

iii. Decelerating the fluid leaving the impeller, to minimise exit losses.

Flow velocity and whirl coefficients are two coefficients giving the relative indices for the mass and energy transfer; these are defined as:

$$\text{Flow-velocity coefficient} = \frac{6Q}{\pi^2 D^2 BN} = \frac{f}{u} = \lambda \quad \ldots (13)$$

$$\text{Whirl coefficient} = \frac{w}{u} = \alpha \quad \ldots (14)$$

The hydraulic efficiency can then be put as:

$$\eta_H = \frac{wu}{gH} = 2\alpha\phi^2 \quad \ldots (15)$$

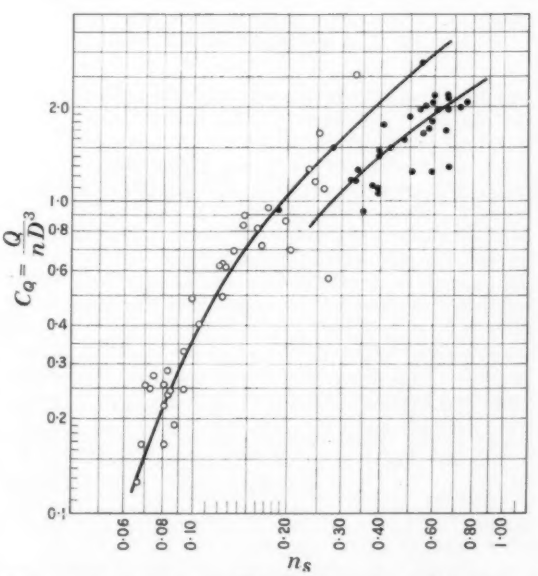


Fig. 6. Discharge coefficient plotted against shape number

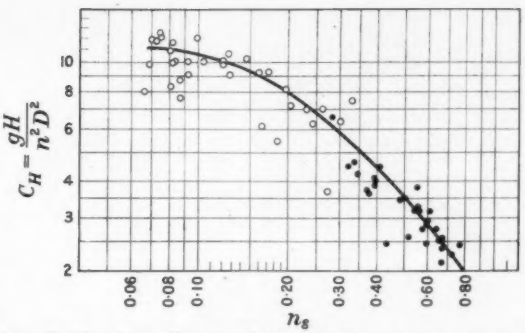


Fig. 7. Head coefficient plotted against shape number

Fig. 15 shows the trend for the flow and whirl coefficients. It can be readily seen that the whirl coefficient gives a direct measure for the energy transfer per unit mass of the flowing water per unit peripheral speed of the turbine wheel, as the energy transfer per unit mass of the flowing water

$$= wu = \alpha u^2$$

Furthermore, the portion of the available water energy that will be converted into kinetic energy before entering the turbine wheel can be put as:

$$\frac{\frac{1}{2}\rho w^2}{\rho g H} = \tfrac{1}{2}\alpha\eta_H \quad \ldots (16)$$

Consequently the whirl coefficient gives an indication of the importance of the stationary accelerating passage, whether this be in the form of guide blades or of a Pelton-wheel nozzle, in influencing the turbine efficiency. Generally speaking, all the previous coefficients completely define the kinematics of the flow at all its stages while passing through the turbine till it finally leaves the draft tube.

Loss Analysis

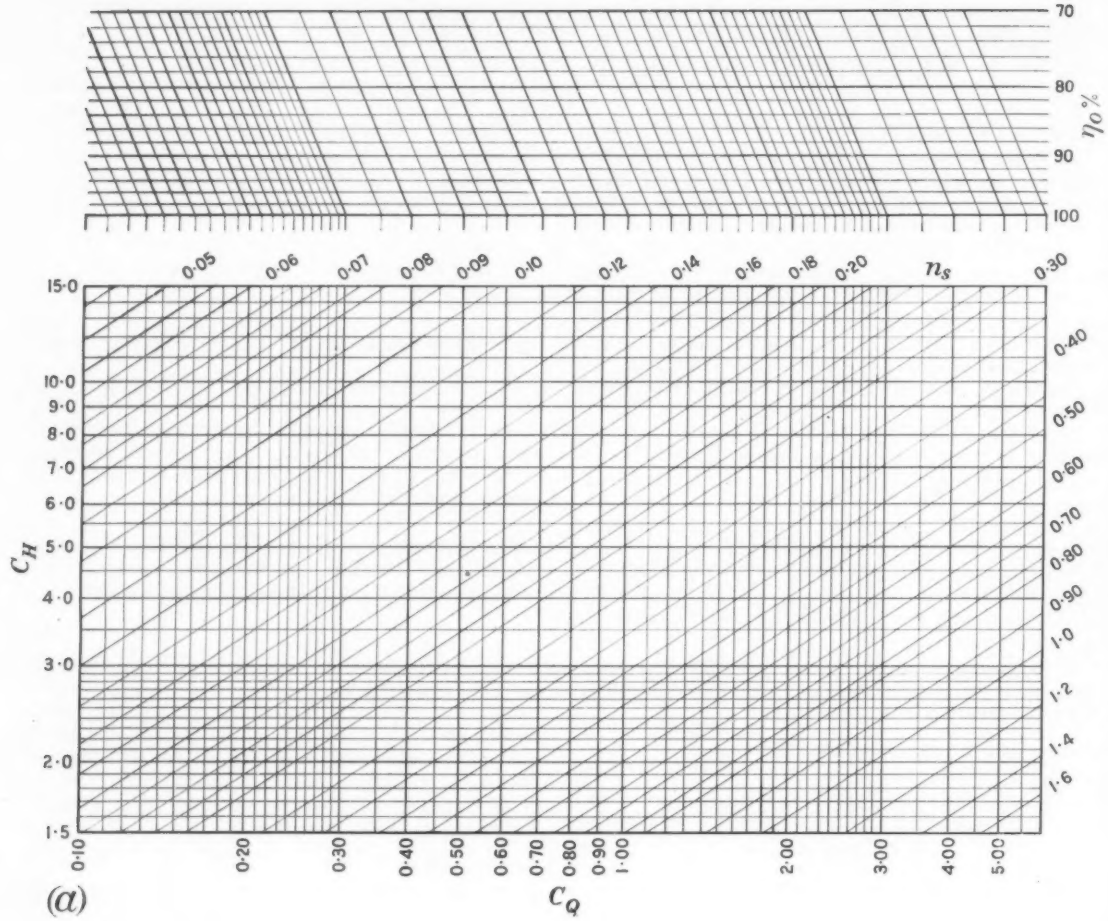
Analysis of the losses occurring in the turbine proper, including the approach and exit passages, and correlating these even qualitatively with the design variables whenever the quantitative study becomes tedious, will help in selecting the optimum values for the design variables most suited to the prevailing conditions. The major part of these losses can be grouped under the following items:

1. Losses taking place in the scrollcase and guide blades during the process of converting the assigned portion of the available energy into kinetic energy.
2. Losses taking place in the runner, whether due to skin friction and turbulence in the runner passages or during the process of energy exchange between the flowing water and the runner blades.
3. Losses taking place in the draft tube while recuperating part of the excess kinetic energy at the runner exit as well as the exit losses of the draft tube.
4. Leakage losses.
5. Disc friction.

Losses in Scrollcase and Guide Blades: The function of the scrollcase and the guide blades is to accelerate the water and impart to it the assigned amount of angular momentum prior to entering the turbine runner. The losses at this stage can be put as:

$$\Delta_1 = \frac{h_{L1}}{H} = (1 - \eta_G)\frac{f^2 + w^2}{2gH} = (1 - \eta_G)(\psi^2 + \alpha^2\phi^2) = \phi^2(1 - \eta_G)(\lambda^2 + \alpha^2) \quad \ldots (17)$$

where η_G = the efficiency of the scrollcase and guide blades in converting part of the water total energy



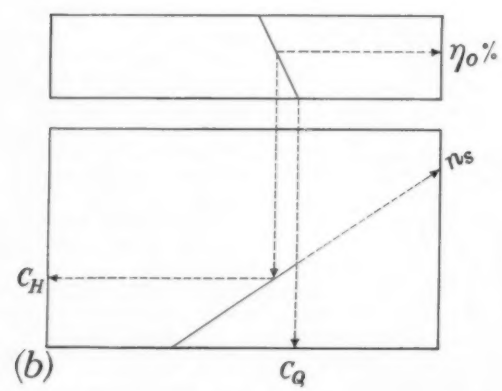


Fig. 8a. Nomogram relating discharge and head coefficients with shape number and turbine efficiency
Fig. 8b. Key for nomogram in Fig. 8a

into kinetic energy. Fig. 16 shows these losses as a percentage of the effective head for different values of guide blade efficiencies against shape number.

Losses in the Runner: The losses occurring in the runner can be subdivided into two distinct groups:

i. Losses due to skin friction and turbulence taking place in the runner passages.

ii. Losses occurring during the process of energy exchange between the flowing water and the impeller blades.

The first part of the hydraulic losses takes place from the first instant when the inflowing water enters the runner at the leading edges of its blades. These losses are made up of several components, e.g. losses due to contraction of the flowing stream caused by the blade thickness, curvature and acceleration imposed upon the flow through the passages between the adjacent blades, and finally exit losses caused by wakes formed downstream of the trailing edges of the blades. An attempt to assess these losses quantitatively would be rather ambiguous, and a qualitative approach will therefore be followed. Following D'Arcy's formula for assessing frictional losses in a given passage it can be shown that these losses, as a ratio to the effective operating head, can be put as:

$$\Delta_2 = \frac{h_f}{H}\alpha^1\frac{Z}{s}\cdot\frac{v_{r1}^2}{2gH}$$

$$= \frac{Z}{s}\cdot\phi^2\left[(1-\alpha)^2+\lambda^2\right] \qquad \ldots (18)$$

where:

Z = number of the blades,

s = impeller breadth ratio to its mean diameter,

v_{r1} = water velocity at inlet to the blades and relative to the impeller.

Fig. 17 shows the result of this qualitative study.

The second portion of the runner losses, i.e. losses occurring during the process of energy exchange, though quite likely less serious than the first part of the runner losses, is nevertheless difficult to assess quantitatively. It can be stated, however, that these losses are closely related to the average dynamic blade loading. This second item of impeller hydraulic loss can be stated, therefore, to be proportional to:

$$\Delta' {}_2 a^1 C_{Ld} = \frac{\Delta p_d}{\rho g H} = \frac{\pi \lambda s a \phi^2}{\xi \zeta Z} \qquad \ldots (19)$$

where:

$\Delta p_d = \dfrac{60 \rho Q w u}{\xi \zeta D^3 Z \Omega}$

Ω = impeller speed in radians per second.

Figs. 17 and 18 give the qualitative analysis for the impeller losses. These clearly illustrate the known fact that better efficiencies can be achieved by Kaplan units than by Francis units at specific speeds of about 350 metric. Furthermore, the average dynamic blade loading is closely related to the cavitation phenomenon. The dotted curve shown in Fig. 18 represents the average trend for the Thoma cavitation parameter. The obvious similarity between the trends of both parameters, i.e. dynamic blade loading coefficient and Thoma factor, is quite understandable.

Losses in the Draft Tube: The draft tube represents an important item influencing the design aspects of hydro-electric plants, and closely affects the overall efficiency of the plant and cavitation risks. Besides, it represents a major part in the civil work of the plant, and in cases of excessive excavation it introduces a factor influencing the economics of the plant.

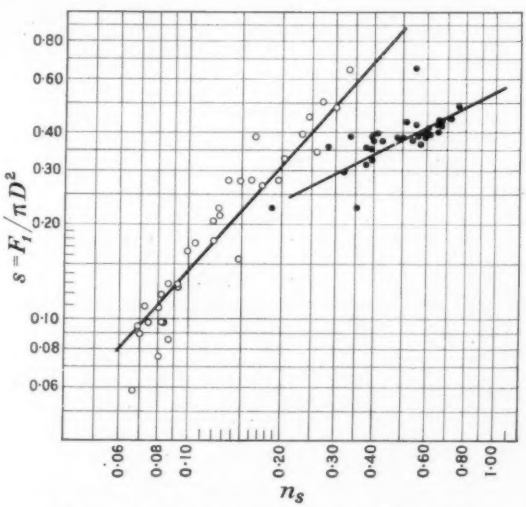


Fig. 9. Runner inlet flow-area coefficient

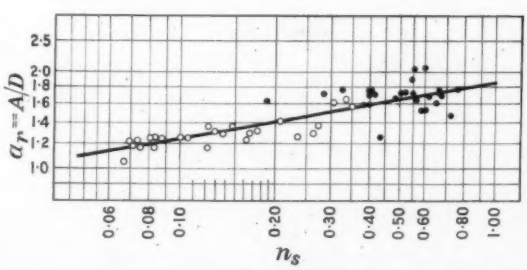
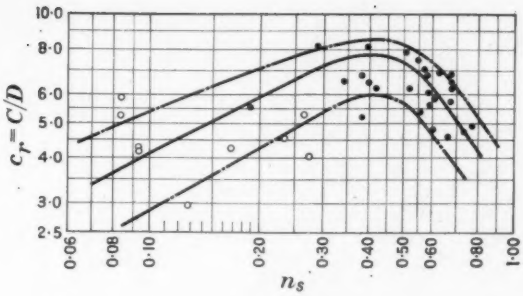


Fig. 10. Diameter ratio for guide-blades pitch circle



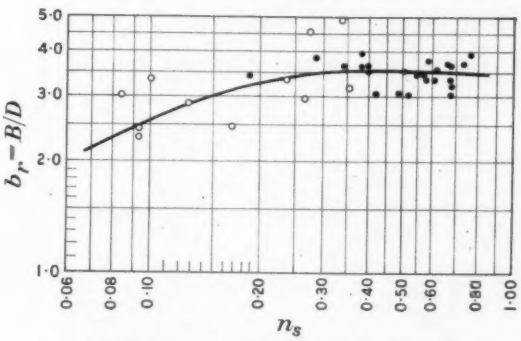


Fig. 11. Draft-tube length and depth ratios

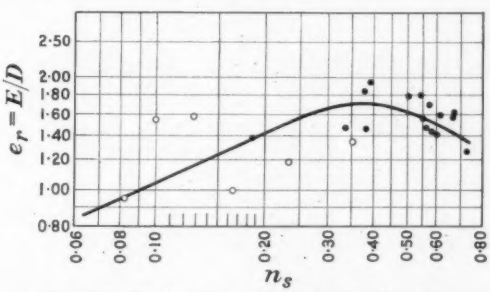


Fig. 12. Draft-tube exit area depth ratio

A draft tube, Fig. 3*b*, is in effect a recuperator, the purpose of which is to regain part of the kinetic energy leaving the turbine wheel, thus reducing the exit losses to an economically reasonable magnitude. Exit losses can be put as:

$$h_{ex} = \frac{f_4^2}{2g} + h_L \qquad \ldots (20)$$

and the head gained in the draft tube will be:

$$h_g = \frac{f_3^2}{2g} - \frac{f_4^2}{2g} - C_L \frac{(f_3 - f_4)^2}{2g}$$

where C_L = the draft-tube-loss coefficient.

The exit losses, as a ratio to the effective head on the turbine, can be put as:

$$\Delta_3 = \psi_4^2 + C_L(\psi_3 - \psi_4)^2 \qquad \ldots (21)$$

and the corresponding expression for the head gain as a ratio to H the effective head will be:

$$C_g = \psi_3^2 - \psi_4^2 - C_L(\psi_3 - \psi_4)^2 \qquad \ldots (22)$$

Furthermore, the draft-tube efficiency defined as the ratio of the head gained to the effective head may then be put as:

$$\eta_{DT} = (1 - C_L)\left(1 - \frac{\psi_4^2}{\psi_3^2}\right) \qquad \ldots (23)$$

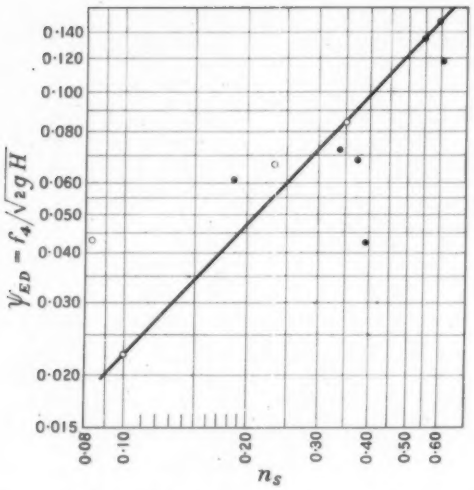


Fig. 13. Flow ratio based on draft-tube exit area

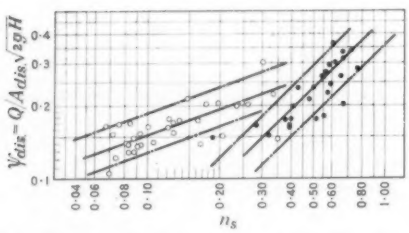


Fig. 14. Flow ratio based on distributor-flow area: $A_{dis.}$ *(*$A_{dis.} = \pi AB_{dis.}$*)*

Obviously the head gained in the draft tube plays an important role regarding cavitation risks, and in some cases a lower draft-tube efficiency may be advisable in the light of cavitation possibilities. Fig. 19 shows the head-gain and exit-loss coefficients for Francis and Kaplan turbines corresponding to different draft-tube efficiencies.

In addition to the above-mentioned hydraulic losses, there are other mechanical losses. These can be put as:

a. Disc-friction losses.
b. Leakage losses through impeller sealing rings, glands and stuffing boxes.
c. Main-bearing losses.
d. Power needed for operating the governing system.

Only the first two items will be considered in the present study, as being closely related to the design variables of the unit. Though these two items originate fundamentally from the dynamics of the fluid within the turbine unit, yet they are quite distinct in nature from the other hydraulic losses.

Disc Friction Losses: The frictional-torque coefficient due to disc friction experienced on one side of a disc rotating in a fluid medium is known to be:

$C_M = 0{\cdot}0622 R_n^{-0{\cdot}2}$

for Reynolds number above 3×10^5

and

$C_M = 2{\cdot}67 R_n^{-0{\cdot}5}$

for Reynolds number below 3×10^5

where $R_n = \dfrac{\Omega D^2}{4\nu}$

To take into account the frictional torque due to the sealing rings, etc., the resultant torque due to all types of disc friction will be assumed as being:

$$T_D = \tfrac{1}{32}\rho C_M \Omega^2 D^5 \qquad \ldots (24)$$

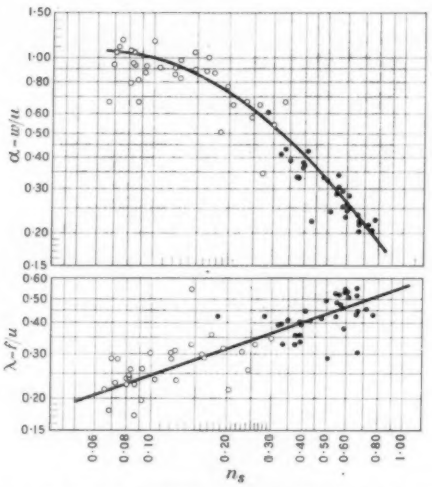


Fig. 15. Whirl and flow coefficients plotted against shape number

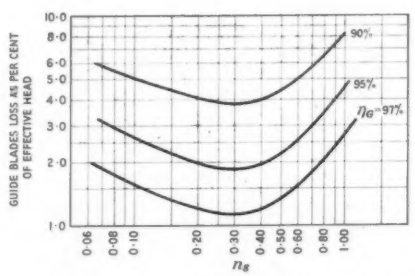


Fig. 16. Losses in scrollcase and guide blades

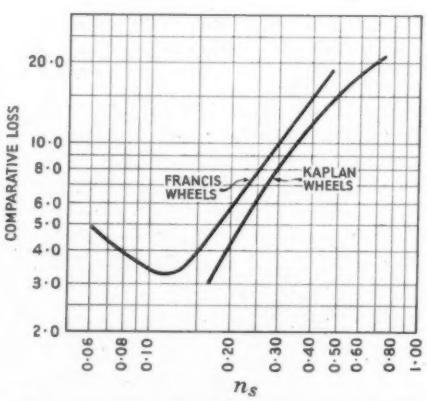


Fig. 17. Comparative friction and turbulence losses in the runner

but the useful hydraulic torque can be put as:

$$T_H = \tfrac{1}{2}\rho Q w D$$

$$= \frac{\pi\rho}{8} D^5 s a \lambda \Omega^2 \qquad \ldots (25)$$

Now the losses due to disc friction can be put as being approximately equivalent to:

$$\Delta_a = \frac{T_D}{T_H} = \frac{C_M}{4\pi s a \lambda} \qquad \ldots (26)$$

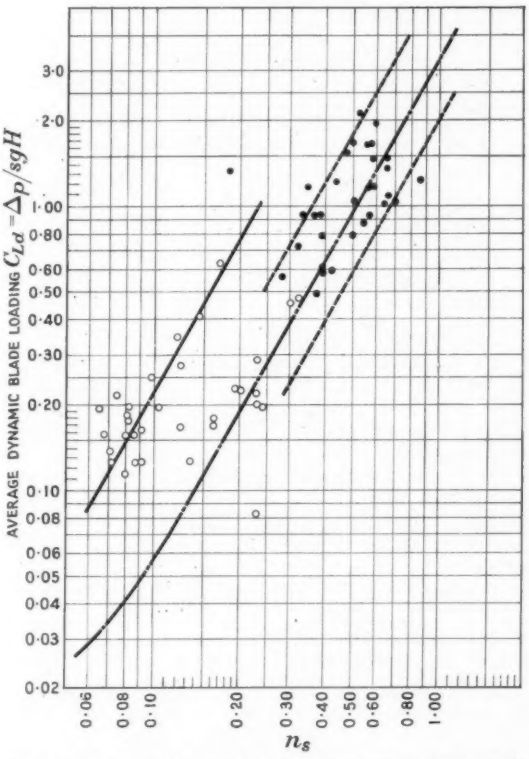


Fig. 18. Average dynamic blade loading and Thoma's cavitation parameter σ

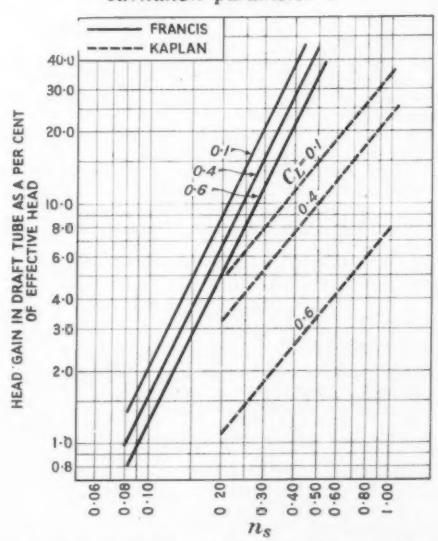


Fig. 19a. Head gain in draft tube for varying draft tube loss coefficient C_L

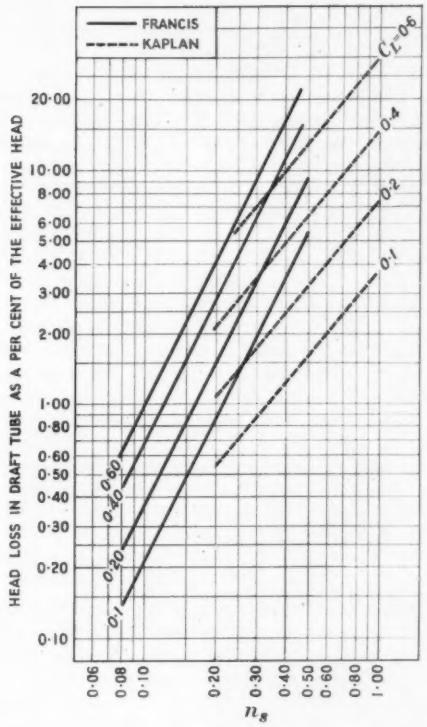


Fig. 19b. Head loss in draft tube for varying draft-tube loss coefficient C_L

Fig. 20 illustrates the trend for the percentage loss due to disc friction for Francis runners of varying specific speeds and Reynolds numbers.

Leakage Losses: The main part of the leakage losses takes place between the runner and the stayring and draft tube. Here again, it is rather difficult to make a quantitative study covering the whole range of water turbines, and a qualitative survey will be followed, leading to some sort of comparative estimate of leakage losses.

The pressure head causing leakage can be approximately put as:

$$H_L \cong H - \frac{w^2}{2g} \qquad \text{for Francis wheels}$$

where w = the whirl velocity of the inflowing water before entering the impeller at its mean diameter,

and $$H_L \cong H - \frac{w_0^2}{2g} \qquad \text{for Kaplan wheels}$$

where w_0 = the whirl velocity of the inflowing water before entering the runner at its outermost diameter.

It can be shown that the leakage flow as a ratio to the main through flow for Francis turbines can be put as:

$$\Delta_{LF} a^l \frac{D^2(H - w^2/2g)^{\frac{1}{2}}}{D^2 sf} = \frac{\sqrt{(1 - \phi^2 a^2)}}{s\lambda\phi} \qquad \ldots (27)$$

As for Kaplan turbines, the following expression will give the corresponding ratio for leakage flow to the main through flow:

$$\Delta_{LK} a^l \frac{D_0^2[H - (w^2/2g)(1 - \frac{1}{2}s)^2]}{D^2 sf}$$

$$= \frac{\sqrt{[1 - a^2\phi^2(1 - \frac{1}{2}s)^2]}}{(1 - \frac{1}{2}s)^2 s\lambda\phi} \qquad \ldots (28)$$

where $\frac{D_0}{D} = \frac{1}{1 - \frac{1}{2}s}$

D_0 = outer diameter of the impeller.

Fig. 21 illustrates the qualitative trends for the relative leakage losses for Francis and Kaplan turbines as computed by expressions 27 and 28. It should be noted that each curve, i.e. for Francis and Kaplan types, gives the relative leakage loss for each class of turbines separately, and that these two curves need not give a comparative representation for leakage losses for the two classes of turbine type relative to each other.

The above study concerning loss analysis for water turbines is based on the average trend of current design practice for existing plants, executed by a variety of major turbine manufacturers, in several parts of the world. Needless to say, this analysis may equally well be used for the purpose of studying the effect upon operational and other factors, of varying any of the design variables, geometrical or kinematic, from its value as recommended by the average trend. It is only to be expected that particular prevailing conditions may well neccessitate such a deviation from current practice.

Acknowledgment

The authors are happy to acknowledge the kindness of the following water-turbine manufacturers for supplying several of their valuable drawings, technical information and technical reviews which helped considerably in making this study: A. B. Karlstads Mekaniska Werkstad, Karlstad, Sweden; Ateliers de Constructions Mecaniques de Vevey, Vevey, Switzerland; Allis-Chalmers, Wisconsin, U.S.A.; Boving and Co. Ltd., London, England; Construzioni Meccaniche Riva, Milano, Italy; English Electric Co. Ltd., Stafford England; Escher Wyss, Zurich, Switzerland; Franco Tosi, Legnano, Italy; J. M. Voith, Heidenheim, Germany; Neyrpic, Grenoble, France; Nydqvist & Holm Aktiebolag, Trollhattan, Sweden; S. Morgan Smith Co., York, Pennsylvania, U.S.A.

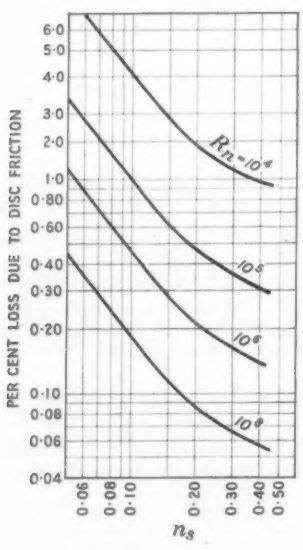


Fig. 20. Percentage loss due to disc friction for different Reynolds number ($R_n = \Omega D^2/4\nu$)

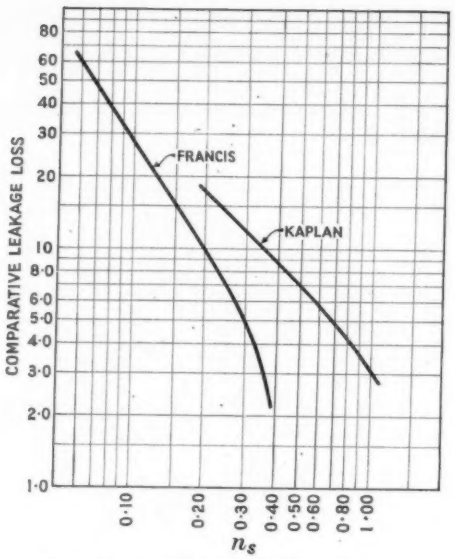


Fig. 21. Comparative leakage losses

REFERENCES

CREAGER, W. and JUSTIN, J., "Hydroelectric Handbook," Second Edition.

DAVIS, C. V., "Handbook of Applied Hydraulics," Second Edition.

BARROWS, H. K., "Water Power Engineering," Third Edition.

BOUSSUGES, P., "Cours de Machines Hydrauliques."

SPANNHAKE, W., "Centrifugal Pumps, Turbines and Propellers."

KELLER, C., "Common Principles and Research for Compressors and Pumps," *Escher Wyss News*, vol. XIV, 1941.

SUESS, A., "Francis Turbines of 115,000 h.p." *Escher Wyss News*, vol. 15/16, 1942/43.

KELLER, C., "Scientific Research work for turbines," *Escher Wyss News*, vol. 15/16, 1942/43.

GERBER, H., "Kaplan Turbines for the large power stations of Donzère-Mondragon on the Rhône and Aswan on the Nile," *Escher Wyss News*, vol. 25/26, 1952/53.

OSTERWALDER, J., "Kaplan Turbines for High heads," *Escher Wyss News*, vol. 25/26, 1952/53.

GYSI, G., and SCHNEEBELI, F., "Francis and Impulse Turbines for high pressures," *Escher Wyss News*, vol. 25/26, 1952/53.

NAG, P. C., and MADHAVAN, K., "Data for Preliminary Estimates," WATER POWER, vol. 7, 1955, pp. 214.

"Development in the Ångerman Catchment, part III," WATER POWER, vol. 7, 1955.

MARCINOWSKI, H., "Kennwerte fur Stromungsmaschinen," VDI Berichte, Bd. 3, 1955.

WUCHERER, J., and VAUCHER, R., "High pressure Kaplan Turbines," *Escher Wyss Technical Review*, vol. 29, 1956.

SADEK, R., and SINBEL, M., "Non Dimensional Approach to the Design of Rotodynamic Pumps, Fans & Blowers." *The Bulletin of the Faculty of Engineering*, Cairo University, 1956/57.

VITVAR, M., "Ten Bladed Kaplan Turbine," WATER POWER, vol. 9, 1957, pp. 446.

ZANOBETTI, D., "Characteristics of Francis Turbines," WATER POWER, vol. 11, pp. 96, 1959.

NOMENCLATURE

C_H = head coefficient = $\frac{gH}{n^2D^2}$

C_{LA} = coefficient of the average dynamic blade loading

C_L = the draft-tube head-loss coefficient

C_M = disc friction moment coefficient

C_Q = discharge coefficient = $\frac{Q}{nD^3}$

D = the runner mean diameter

F_1 = runner inlet flow area

f = flow velocity at inlet to turbine wheel

g = gravitational acceleration

H = effective head in metres of water

h_g = head gain in the draft tube

h_L = head loss in the draft tube

h.p. = turbine output shaft horse power
N_s = specific speed
N = runner rotational speed in revolutions per minute
n = runner rotational speed in revolutions per second
n_s = shape number
Q = flow rate passing through the turbine at design point
u = wheel peripheral speed at mean diameter
$s = \frac{F_1}{\pi D^2}$
v_{rl} = water velocity relative to the runner at its mean diameter
w = whirl velocity of the inflowing water at the runner inlet mean diameter
w.h.p. = water horse power input to turbine
Z = number of the runner blades
ρ = water density
Ω = runner rotational speed in radians per second
ψ = flow ratio $= \frac{f}{\sqrt{(2gH)}}$
φ = speed ratio $= \frac{u}{\sqrt{(2gH)}}$
λ = flow coefficient $= \frac{f}{u}$
α = whirl coefficient $= \frac{w}{u}$

η_0 = turbine overall efficiency $= \frac{\text{h.p.}}{\text{w.h.p.}}$
η_H = turbine hydraulic efficiency $= \frac{wu}{gH}$
η_G = efficiency of scroll casing and guide blades
Δp_d = The average dynamic blade loading
ξ_D = distance from the axis of the runner to the point of action of the total resultant of the blade dynamic pressure
ζD^2 = the blade projected area on the meridional plane
θ = angle between the absolute water velocity entering the runner at its mean diameter and the tangential direction
$= \tan^{-1}\frac{\lambda}{\alpha}$
β = angle between the water velocity relative to the runner at its mean diameter and the tangential direction
$= \tan^{-1}\frac{\lambda}{1-\alpha}$

Key to points in the curves:
○ : Francis turbines
● : Kaplan turbines

New Zealand Annual Report

The Annual Report of the New Zealand Ministry of Works gives the usual summary of the state of hydro-electric supply for the year ended March 31, 1960. To avoid damage to the scenery at Aratiatia, which is a popular tourist spot, construction is being carried out from each end without building roads alongside the rapids. This station will contain three 30,000 kW sets and operate on a head of 100 ft. Power is first scheduled for April 1964. All the design work for the Atiamuri station has been completed and three 21,000 kW machines are now in operation. Provision has been made for a fourth set, and when the site has been cleared of constructional activities Atiamuri will have an attractive appearance.

A survey of the river bed at Aviemore has been made and drilling to ascertain the foundation conditions was completed. This site was previously known as Okaitu.

Benmore, the largest scheme to date, was advanced well into its initial constructional stage during the year. The general layout of the earth dam, spillway, intake, penstocks and power house for this 540 MW project has now been firmly defined and the detailing of the river diversion culvert structures was completed. Penstocks of 17 ft. 6 in. internal diameter are to be used and will be constructed of prestressed concrete. Earthworks involved 150,000 cu. yards of core trench and the stripping of 250,000 cu. yards of common material. The total earthworks at the site amounted to about 1,500,000 cu. yards. The Hawea lake-control dam is now completed and will be invaluable for storing water for Roxburgh to augment the low winter flows which can occur in the Clutha.

Mangakino is the headquarters for the hydro-electric station being built on the Waikato river. During the year an average labour force of 1,572 men was employed and the supervisory and administrative staff numbered over 350. Maraetai II, the peak-load power station of 180,000 kW capacity, will form the subject of a subsequent article in this journal. It is notable for bold rock excavation work and it will be sufficient to say here that all the work is going according to schedule. The Ohakuri station will be the next to produce power and will probably be in production in late 1960. It is a four-unit station with 28,000 kW generators and has an earth dam and required heavy rock excavation to fit intakes, penstocks and power house into the topography.

At Roxburgh the second four machines, each of 160,000 kW capacity, are now being installed.

BICC at Kariba. Particulars of the 330,000 V cables which British Insulated Callender's Cables Limited have supplied to the Kariba scheme are given in the May issue of the BICC Bulletin. These particulars include design data, manufacturing details, protection against corrosion, testing, transportation and installation.

G.E.C. Control Board Components. Technical Description No. 403, received from The General Electric Co. Ltd., of England, gives particulars of their components for fitting into control boards, affording infinite flexibility of choice and covering different requirements and practices.

Boving & Co. Ltd. have issued a brochure on the turbines they have installed at Kariba. The Company rightly feel that so much attention has been given to the civil-engineering side of the scheme that their publication will do something towards emphasising the size and importance of the turbine plant, each unit of which will be capable of producing 180,000 h.p. under maximum conditions, but in practice will be limited to 140,000 h.p. to avoid overloading the generator.

International Power and Engineering Consultants Limited. This organisation, whose address is 570 Dunsmuir Street, Vancouver 2, British Columbia, Canada, have sent us an illustrated booklet describing their organisation and outlining some of their major works in the engineering, construction and commissioning of hydro-electric projects. The work includes the carrying out of initial surveys, feasibility studies as well as building transmission networks, substations and distributing systems. At present the company is engaged in the design of the Peace River development where 9 million horsepower is attainable. The organisation is under the leadership of Sir Andrew MacTaggart (Chairman), Dr. A. E. Grauer (Deputy Chairman), and Dr. T. Ingledow (President and Chief Executive Officer).

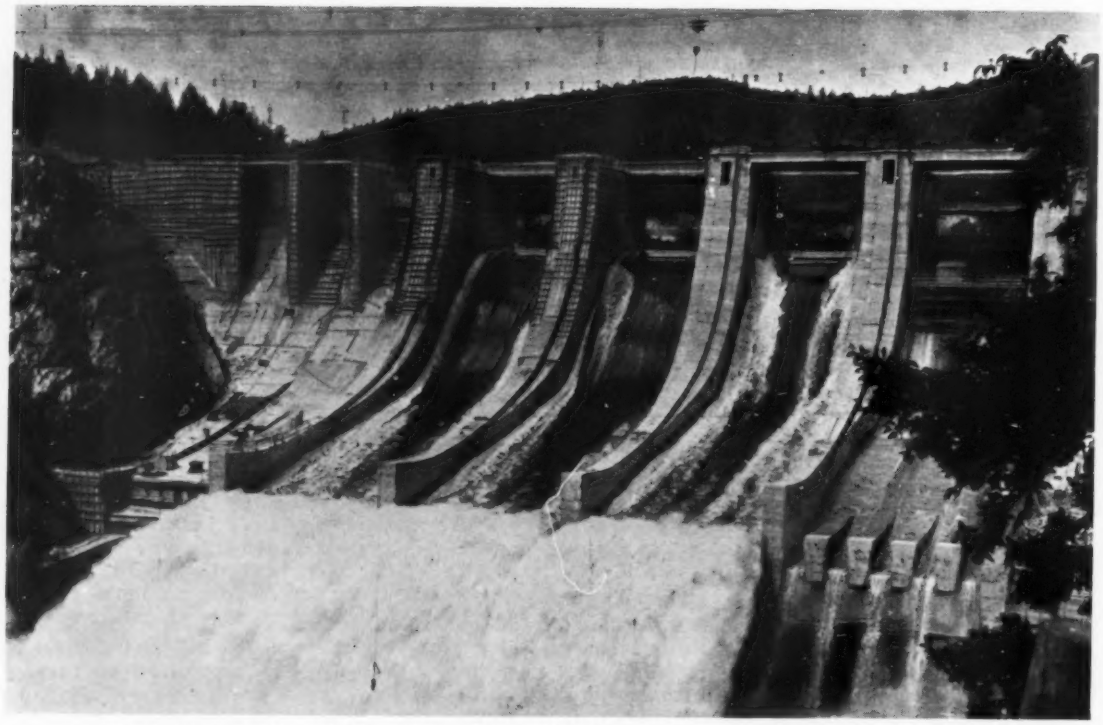


Fig. 1. Slapy station discharging a flow of 2,400 cu. m. per sec. into the stilling basin

Slapy Power Station

An account is given of the civil, mechanical and electrical design features of this important 50 MW plant on the Vltava in Czechoslovakia

By. Prof. Ing. Dr. MIROSLAV NECHLEBA*

PART ONE

AS in other countries where coal is the basis of power production, Czechoslovakia utilises her water power almost exclusively for covering peaks in the national power network. Her water-power plants, therefore, are built in conjunction with high dams, and plants of this kind offer the advantage of being constantly ready to supply power owing to the fact that automatic hydraulic stations can be put into operation from complete standstill and connected to the network within a very few minutes.

The Vltava Cascade

For the construction of water-power plants in Czechoslovakia, three rivers have mainly to be considered: the Vltava, the Váh and the Danube. In Bohemia, the western part of the Republic, it is the River Vltava which lends itself best to the erection of plants with dams providing large water supplies. In spring the river abounds in water and a substantial head enables the flow to be utilised to advantage. For this reason, the so-called Vltava Cascade is being built and a system of consecutive reservoirs—the purpose of which, from the standpoint of power production, is to balance the discharge in the course of a year or of several consecutive years. The natural supply fluctuates highly, as the maximum flow amounts to 3,000 cu. m. per sec., whereas the average flow in the lower part of the river is only 85 cu. m. per sec. The capacity of the reservoirs has to suffice for covering the peak operation periods of the power plants, and in addition to the demands of power engineers, those of water economists have to be met, who are concerned with ensuring the water supply for irrigation, industry, and the needs of the population. River navigation has also to be taken into consideration, and the hydraulic structures are consequently of the multipurpose type. Twelve stages are planned for the entire Vltava Cascade, as indicated in Fig. 2. The downstream stages, Vrané, Štěchovice and Slapy, as well as the one farther upstream, Lipno, are already in operation.

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The Vrané dam and power plant form the oldest stage, and constitute an equalising barrage at the end of the series. This plant utilises the water continuously, passing a regular water discharge in the direction of Prague. The Štěchovice station, situated above, is designed for taking peak loads. It operates automatically and its capacity is increased by an attached pumped-storage station. The Štěchovice dam forms an equalising barrage for the Slapy station situated above, the latter being even larger in size.

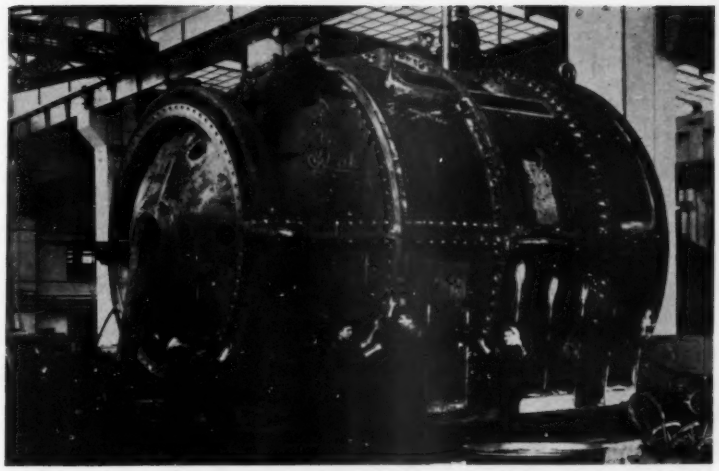


Fig. 3. One of the downstream hollow-jet valves being assembled

Slapy Power Station

The site of the Slapy dam was determined by geological considerations and by the desirability of locating it near the end of the Štěchovice backwater. The dam rests upon the amphibolites of the Jílové area, which are the best suited for the purpose, and is located in quite a narrow section of the valley, the length of the dam crest measuring only 260 m., whereas the height of the crest above the foundation is 65 m. The dam is of the concrete gravity type and contains 330,000 cu. m. of material. Seeing that it retains as much as 270,000,000 cu. m. of water, i.e., 820 cu. m. of water for one cu. m. of concrete, a very favourable ratio of usage of material has been obtained.

In order to protect the upstream face of the dam against aggressive waters it is covered with a double asphalt lining, and within the limits of the water-level fluctuation, the wall is coated with synthetic pitch and aluminium. Below the foundation a grout apron is provided by two rows of drillings 15 m. deep, spaced 4 m. apart.

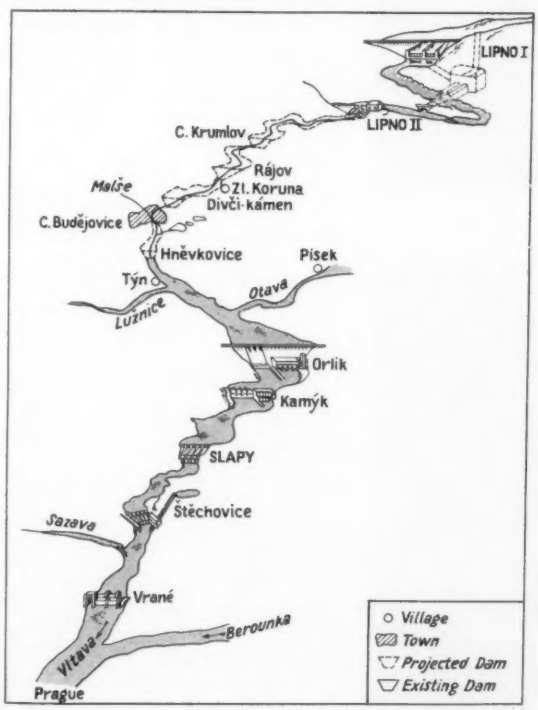


Fig. 2. A map of Vltava River showing existing and proposed dams

Drainage of the dam body is effected by means of a system of vertical drains, 20 cm. in diameter, which run into inspection galleries. The dam is divided into individual blocks by vertical expansion joints which have been sealed by means of pentagonal prisms of reinforced concrete and by copper sheets. For tightening the horizontal expansion joints, reinforced gunite strips, 30 cm. wide and 3 cm. thick, covered with isocryte plates, have been used.

To enable large floods (up to 3,000 cu. m. per sec.) to be discharged, two bottom sluices have been provided, consisting of reinforced conduits 4 m. in diameter, as well as four spillways, each 15 m. wide, designed for an 8·1 m. head on the crest. The bottom sluices are closed on the upstream side by caterpillar sluice gates operated by hydraulic hoists, and, on the downstream side by hollow-jet valves (Fig. 3) operated by electric motors. Each of the bottom valves is able to discharge 200 cu. m. per sec. at the full head of 56 m. The spillways are closed by tainter gates, 8·5 m. high, as seen in the foreground of Fig. 4.

Because of the narrowness of the valley, there was no possibility of the power station being located beside the spillways. To have situated it farther downstream, on the river bank, would have necessitated the construction of an excessively long penstock, thus increasing the loss of head and rendering regulation unfavourable due to waterhammer. For this reason, the power house has been placed directly at the toe of the dam, and water discharged from the spillways is conducted by chutes placed above the power house (Fig. 8). As can be seen from the illustration, a smooth transition is ensured from the spillway to the chute on the roof of the power house whence the water falls into a stilling basin situated downstream of the dam. The end of the chute is provided with concrete splitters to disperse the spilled water and aerate it so as to damp down the major part of its kinetic energy at the point where it hits the stilling basin. These splitters have enabled the length and the depth of the stilling basin to be reduced and the stresses on its floor diminished. The spillway chutes cover part of

Fig. 4. A view of the gate gallery showing a closed tainter gate

Fig. 5. A 1 : 50 model for diversion tunnel tests

Fig. 6. A model of the spillway piers and turbine intake towers

the space between the power house and the dam wall, providing a location for the high-voltage (100 kV) switchgear. A longitudinal section through the dam is given in Fig. 7.

The dam was built under the protection of upstream and downstream cofferdams consisting of earth embankments, the upstream one, 20 m. high, having a concrete core. A diversion tunnel, 10 m. wide and 12 m. high, bypassed the dam site. To determine the required capacity of this tunnel, a curve was used indicating the recorded flows during the last 60 years, and an economic capacity of 800 cu. m. per sec. was chosen, equivalent to a 31·5 year flood.

Tests carried out on models enabled the inlet, the tunnel cross section and the partial lining to be accurately shaped. To safeguard the dam site during the drift-ice period, a segment-shaped wooden gate was built at the outlet of the diversion tunnel which caused the water level inside the tunnel and in the reservoir formed by the upper cofferdam to rise. An ice cover was formed on this reservoir, and the end of the backwater, where ice stoppage occurs, was shifted 10 km. upstream from the construction site. When the construction work was finished, the temporary gate at the end of the diversion tunnel was removed and the tunnel was closed by a reinforced-concrete plug. This plug was made hollow so as to form a caisson which was floated into the tunnel inlet and sunk by filling it with water. This enabled the tunnel to be closed very easily, and when this had been done, a second plug was inserted in the tunnel on the axis of the dam.

Liberal use has been made of prefabricated elements such as brackets, roof plates, girders for the crest bridge of the dam, and the like. A special problem was the method of insulating the roof of the power house against the water flowing over it. Rubber strips cramped into angle irons and strips of copper sheet served for filling the expansion joints. The whole surface has been covered with isocryte plates and glass jute and provided with two hot-applied asphalt coatings.

In the design of the plant, facilities for passing shipping had also to be considered. For sports boats, a four-ton transport car has

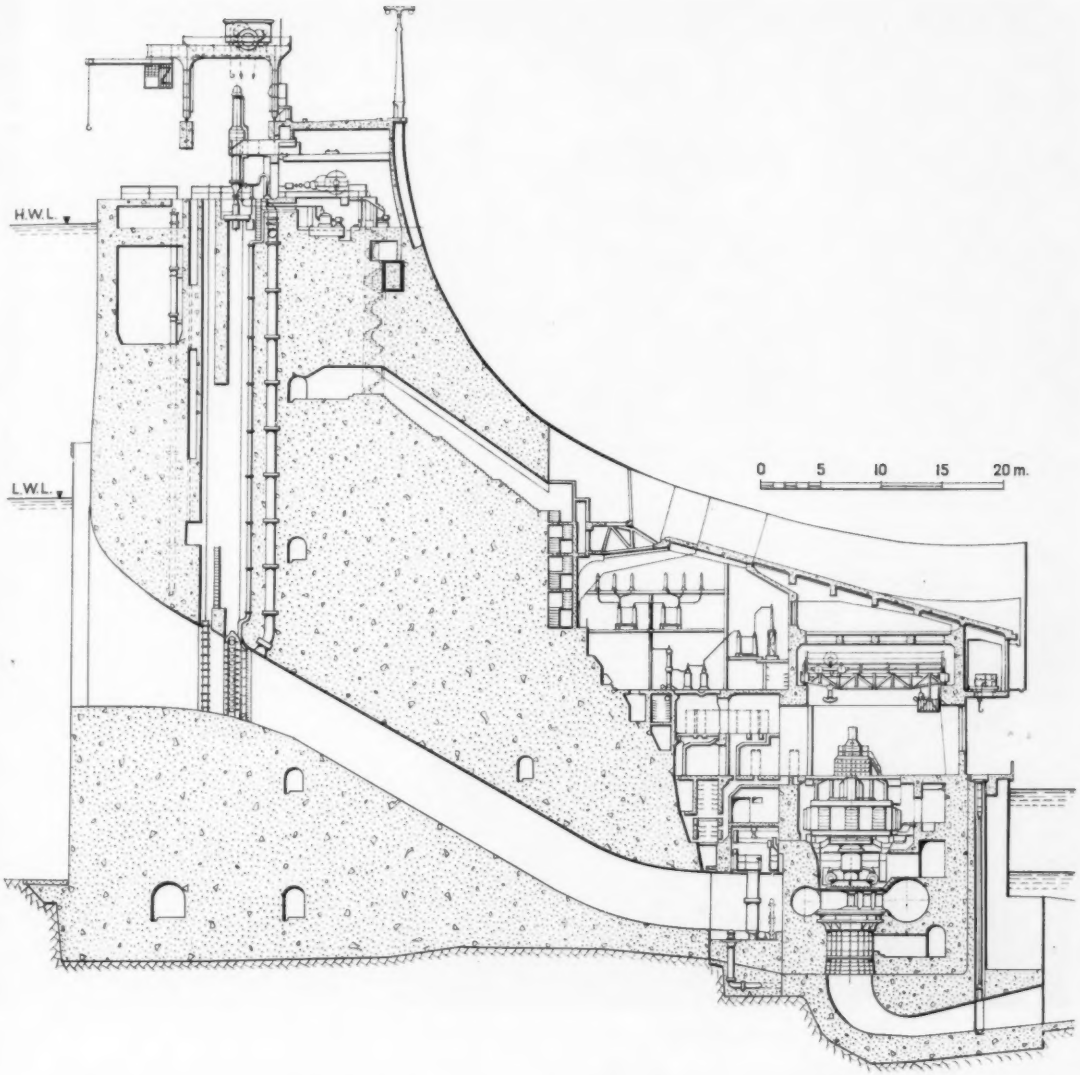


Fig. 7. A longitudinal section through the dam and power station

been provided. Later, the existing diversion tunnel will be used as a communication canal from the tail-water to a high-lift lock chamber designed for 300-ton boats. This chamber will be cut in the rock and provided with economic two-phase filling devices.

The accommodation formerly built for workers employed on the site is now used as a recreation camp.

Three Kaplan turbines are located in the power house below the spillway chutes. Each is built for a maximum flow of 100 cu. m. per sec. and for heads ranging from 56 m. to 24 m. The maximum output of each turbine is 50 MW measured on the coupling, and the average yearly output of the power plant is 300 million kWh. The plant was put into operation in 1954.

Hydraulic Model Research Before Erection

The efficient basic conception of the Slapy plant is due to close co-operation of the chief designer, Ing. L. Záruba, with hydrotechnical research workers under the leadership of Prof. J. Čábelka[9]. Prior to the realisation of the project as a whole, its individual constructional stages were subjected to investigation, amendment and verification, a series of small-scale models being used to prove the suitability and economy of the project.

Fig. 5 shows the model used for testing the diversion tunnel. A model of the site with the adjacent river course was constructed, scaled down to 1 : 50, which made it possible to investigate the flow capacity of the tunnel, its flow as a function of the head, and the division of the water flow into two parts should it exceed the capacity of the tunnel. In that case, some of the water would have passed through the tunnel and the remainder through the construction site, but actually the site was never flooded during erection. However, immediately afterwards and before putting

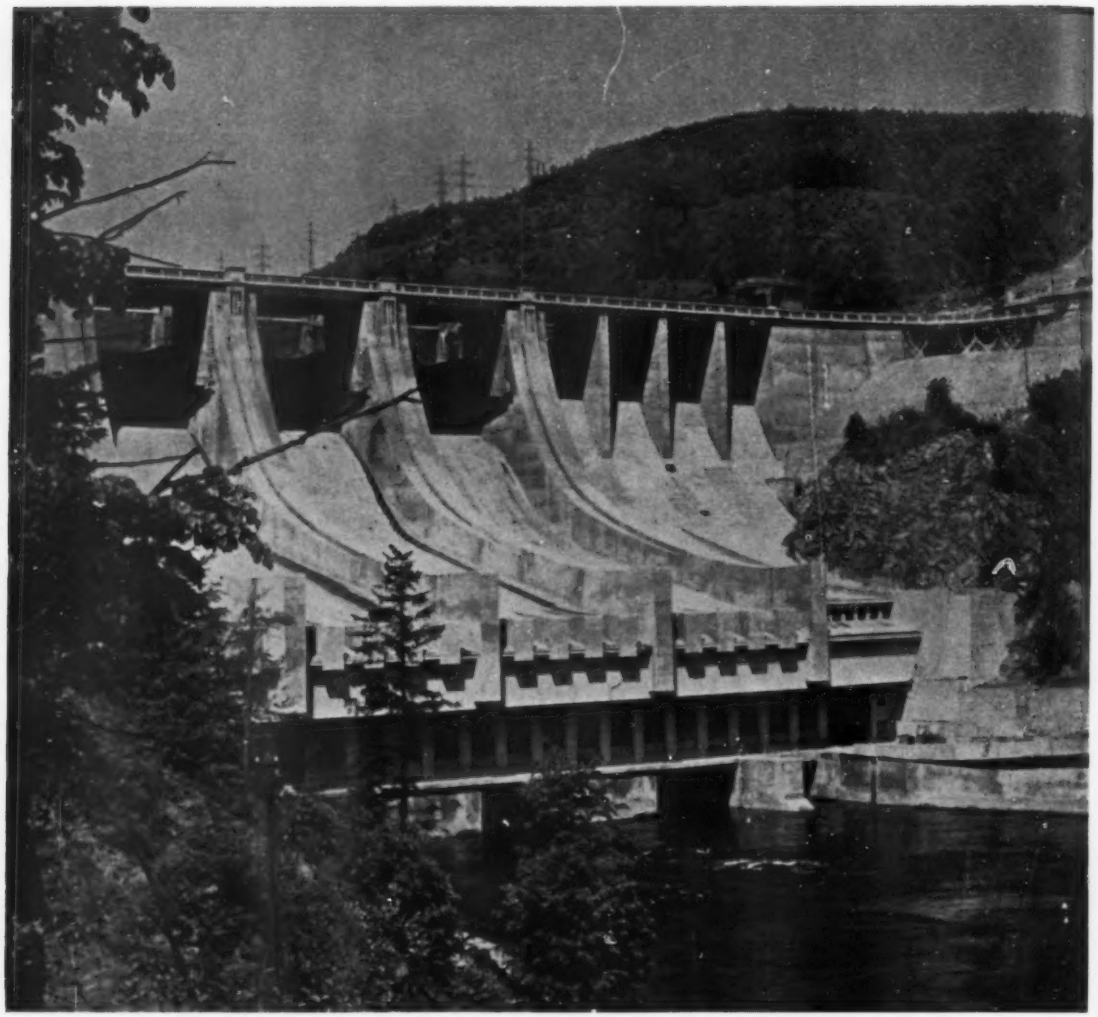


Fig. 8. A view of Slapy dam showing the serrated spillway and station

the plant into operation, high waters rapidly filled the space in front of the dam. Fig. 1 shows the spillway and the bottom hollow-jet valves discharging a flow of 2,400 cu. m. per sec. into the stilling basin.

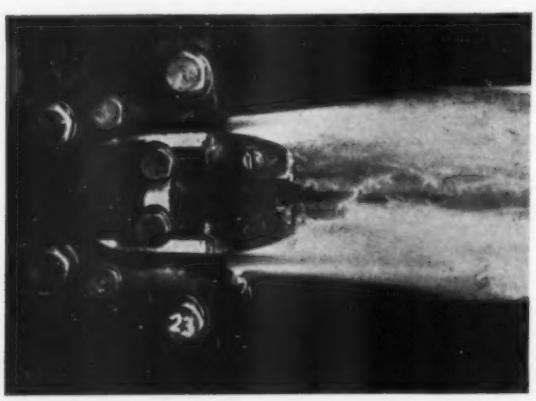


Fig. 9. Model showing the flow through the discharge outlet

The foregoing investigations enabled the tunnel intake to be designed to prevent any flow contraction and also to reduce the possibility of the intake becoming choked. The outlet has also been suitably adapted to direct the water jet parallel to the flow lines of the tailwater. It was found that the downstream part of the tunnel was at no time entirely filled, and it was possible to reduce the cross section of the downstream part of the tunnel.

Models were also used for investigating the operation of the spillway and stilling basin. One of these models is shown in Fig. 11. According to a method suggested by Academician J. Smetana[16], the spillway has been shaped to support the spillway jet. Piezometers placed along the spillway served to measure the pressures, and it was found that undesirable subatmospheric pressures were not created anywhere. Small local under-pressures arose just behind the sill when the tainter gate was partially opened, but these did not appear to be dangerous. A great deal of attention was paid to the splitters at the end of the spillway bucket[1]. The investigation also dealt with the effect

of the spillway flow upon the discharge from the turbine draft tubes. Suitable adaptation resulted in lowering the water level behind the turbines, when the spillway was in operation.

Tests also served to determine the shapes of the noses of the spillway piers, of the turbine intake towers, and of the bottom discharges (Fig. 6). By streamlining the pier noses and placing them some distance in front of the spillway, thus preventing any lateral constriction of the water sheet, unfavourable effects upon the spillway capacity and upon the distribution of stresses over the spillway surface and on the tainter gate have been avoided. The turbine and bottom-discharge intakes are also shaped to eliminate any contraction of flow and to reduce intake losses. Fig. 10 is a view of these towers during erection.

The Bottom Outlets

As already mentioned, the dam is provided with bottom outlets designed to pass the river water after closing the diversion tunnel, to relieve floods, and to empty the reservoir. Hollow-jet valves, one of which can be seen in Fig. 3, are used for regulating the discharge. The valve outlet is 5 m. in diameter, but in spite of its size, the plug is operated by a motor of only 20 h.p., through reduction gears. This favourable feature is due to the perfect hydraulic equilibrium of the plug obtained by careful tests carried out on models at the maker's laboratories. By means of tests carried out on a half-model secured to a glass plate, a suitable shape of the discharge outlet was determined, whether discharging into the atmosphere or under the water level. It proved necessary to provide the central portion with a special hub, as shown in Fig. 9 to prevent eddies when discharging under water, as they are known to cause dangerous vibrations. The rate of aeration required in order to avoid cavitation was also determined. Up to the end of the erection period, after the diversion tunnel had been closed, the discharge devices were continuously in operation and proved absolutely reliable.

(To be continued)

Note: Reference numbers will be found at the end of the concluding article.

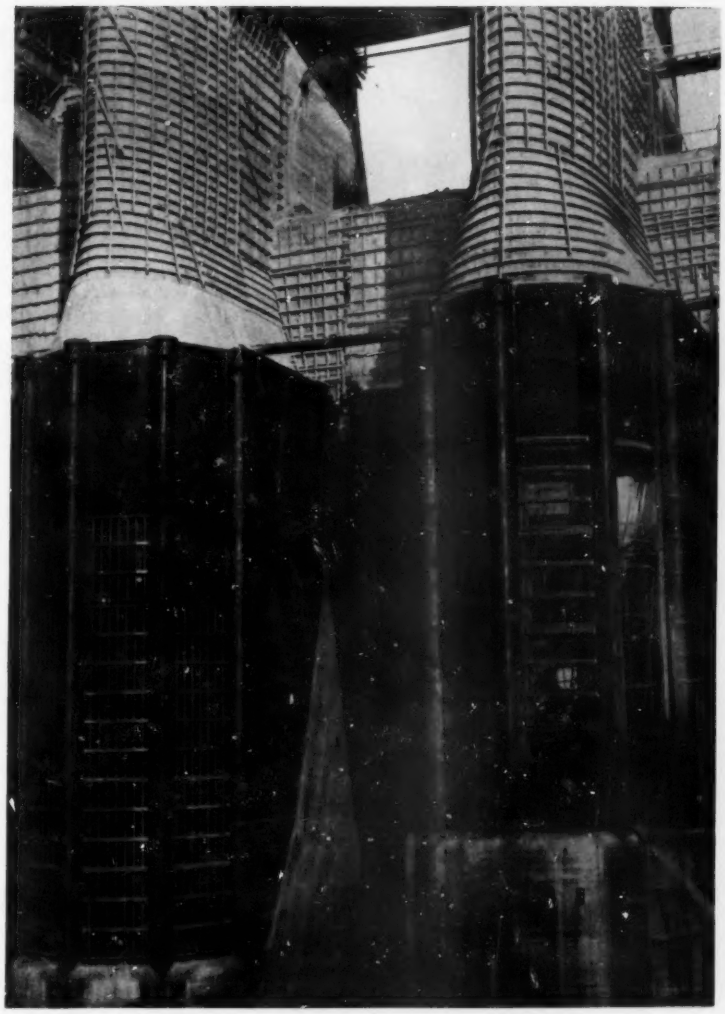


Fig. 10. A view of the intake towers during erection

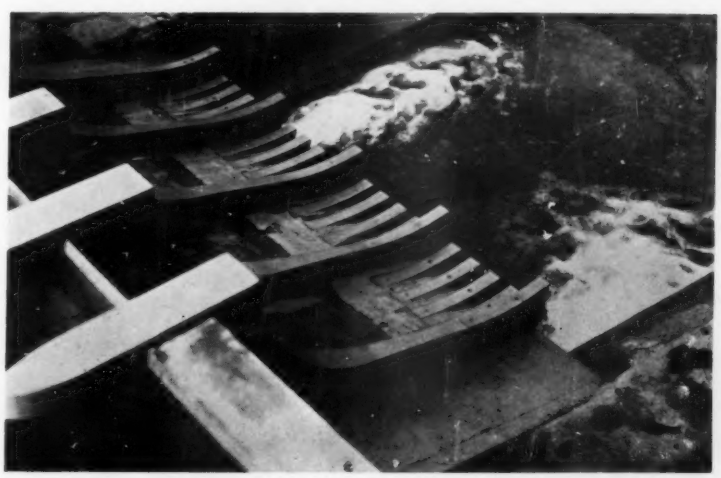


Fig. 11. A model of the Slapy spillway showing the splitters

River Gauging by Helicopter

The author proposes a method of flood-velocity observation by means of floats dropped from a helicopter and photographed, in cases where the natural conditions prevent the employment of normal methods

By M. CAPUCHO VIEIRA

FOR the past three years the author has been in charge of a party engaged in the hydrological survey of the Zambezi River and its tributaries in Portuguese East Africa. Hydrometric work in this region is not easy, particularly during flood seasons, when ground access to most of the places suitably located to provide adequate velocity observations is difficult or impossible, and when the rivers carry hundreds of trees, so that observations by boat become dangerous and the use of current meters practically out of the question. As a study of plans of development very often requires a reasonable knowledge of flood discharge, a method is proposed to observe water velocity under such adverse conditions by using

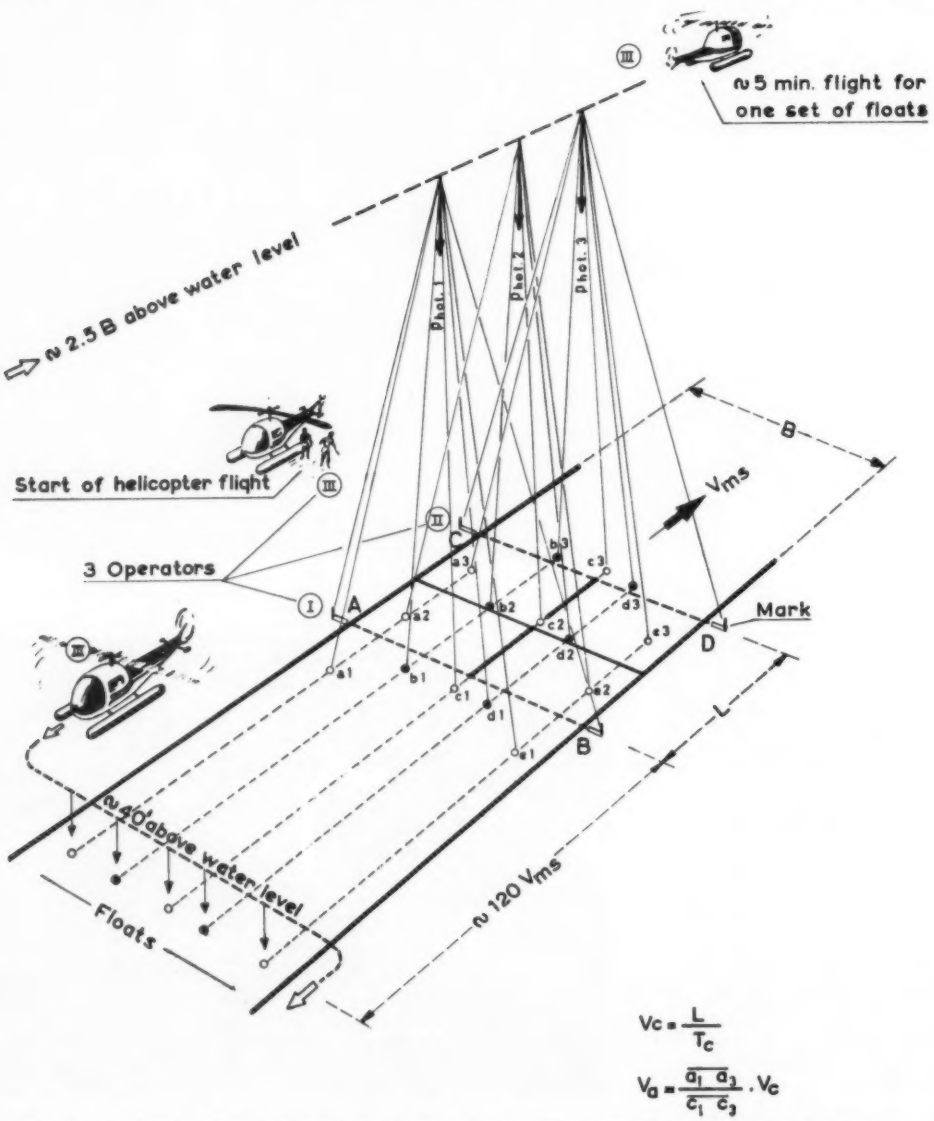


Fig. 1. A sketch of a suggested method of river gauging by helicopter and floats

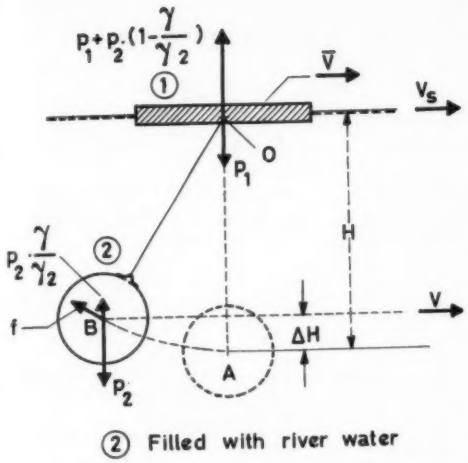


Fig. 2. Illustration of under-surface velocity observation

floats in conjunction with a helicopter. The mean velocity at the gauging section is computed by drawing curves of equal velocity.

Surface-Velocity Observations

The gauging station is prepared during the dry season. Two marks on each river bank define two sections *AB* and *CD* (Fig. 1) for velocity control, between which it is assumed that the mean velocity at any point represents the velocity at the same point of the gauging section. Levels of these four marks are taken with reference to the zero of the gauging scale of the station, and distances *AB*, *AC*, *CD* and *DB* are measured. The cross section of the gauging section is then determined.

The method proposed to observe surface velocity is indicated in Fig. 1 and summarised below:—

(i) A helicopter carries to the station three operators and an adequate quantity of floats.

(ii) Operators I and II, each one with a stopwatch, take up positions close to marks *A* and *C*.

(iii) Operator III, flying in the helicopter, throws down one float and roughly calculates the maximum surface velocity V_{ms}.

(iv) Operator III, flying at about 40 ft. above water level, puts down on the river a set of floats at a distance of about $120V_{ms}$ upstream of section *AB*, in order to provide the helicopter time enough to reach the proper level for taking photographs 1, 2, and 3;

(v) Operators I and II check the time T_c in which float *c* travels the distance *L* from *AB* to *CD*;

(vi) After this, a new set of floats can be operated in the same way.

Velocity of float *c* is given by $V_c = L/T_c$, and the velocity of another float, *a* for instance, is calculated by

$$V_a = \frac{\overline{a_1a_3}}{\overline{c_1c_3}} . V_c$$

$\overline{a_1a_3}$ and $\overline{c_1c_3}$ being taken from photographs 1 and 3.

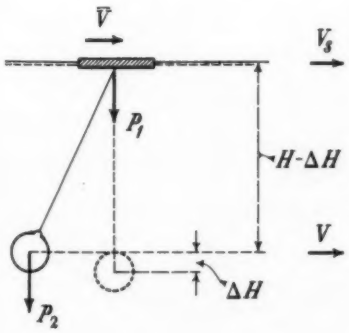
$\frac{P_1}{P_2} = 1$

$\gamma = 1{\cdot}1$

$\gamma_2 = 7{\cdot}2$

$\frac{v}{P_2} = 3{\cdot}47$ cm.³/g.

$g = 980$ cm./sec.²



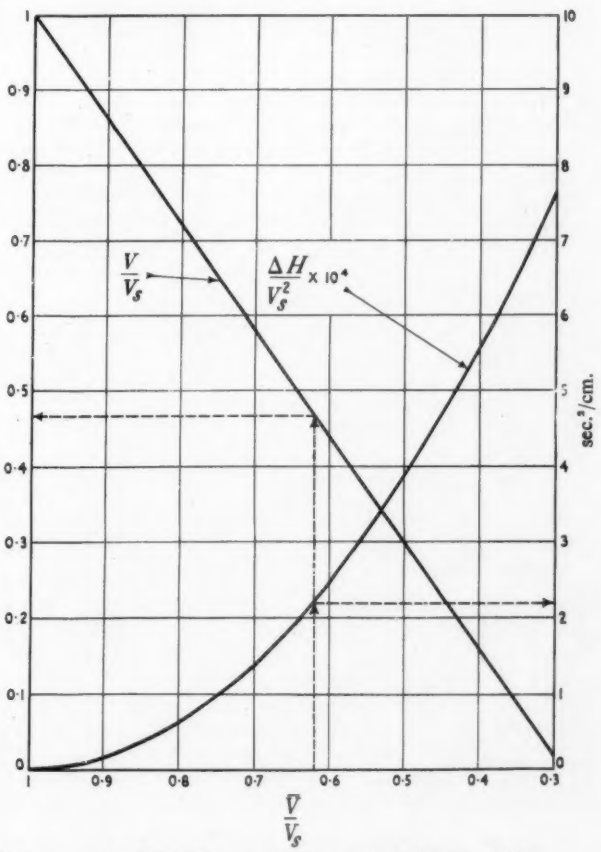


Fig. 3. Calculated graph of V/V_s *and* $\Delta H/V_s^2$ *for a cork float 30 cm. diameter and 3 cm. thick*

Photograph 2 serves to check the constancy of velocity between AB and CD:

$$\frac{\overline{a_1a_2}}{\overline{c_1c_2}}.V_c = \frac{\overline{a_2a_3}}{\overline{c_2c_3}}.V_c = V_a$$

Remarks

(*a*) This method is not suitable for velocity observations on windy days. In any case, it is important for floats to be mainly submerged.

(*b*) Cork-made floats 30 cm. diameter and 3 cm. thick, painted black or white, each weighing 509 g. should be suitable. They are easy to transport and are not expensive.

(*c*) Floats are not recovered.

(*d*) Photographs 1, 2, and 3 are taken when the helicopter flies over the centreline of the river. Any distortion of these photographs can be corrected by means of distances AB, CD, AC and BD, levels of marks A, B, C, and D, and focus of the camera lens. This correction is easier if marks A, B, C, and D lie at the same level.

(*e*) If operator III has a stopwatch actuated by the camera so that it can give the time $T_{1,2}$ between photographs 1 and 2, and the time $T_{2,3}$ between photographs 2 and 3, then there is no need for operators I and II and the whole operation can be accomplished by a crew of two (pilot and one operator) instead of four (pilot and three operators). In this case, the velocities would be calculated by means of the expressions

$$V_a = \frac{\overline{a_1a_3}}{T_{1,3}} \text{ etc.} \quad \text{or} \quad V_a = \frac{\overline{a_2a_3}}{T_{2,3}} \text{ etc.}$$

Under-Surface Velocity Observations

Let us suppose, first, that float 1 travels freely with a velocity V_s (Fig. 2). If we then hang a body, 2, from it at a depth H, the assembly $1 + 2$ will travel with a velocity $\bar{V}$ (smaller than V_s, as velocity usually decreases from surface to bottom), and the hanging body will move from position A to position B, higher than A by ΔH.

Let us take:

V = the velocity that the hanging body would take if it travelled freely at the same depth $H - \Delta H$;

p_1 and p_2 = the weights of float 1 and body 2;

v = the total volume of body 2 (which is filled with water from the river);

γ_2 = the density of body 2;

γ = the density of river water;

g = the gravity acceleration.

The momentum of the assembly $1 + 2$ travelling with velocity $\bar{V}$ equals the sum of the momentums of each travelling freely with velocities V_s and V:

$$\left[\frac{p_1 + p_2.(1 - \gamma/\gamma_2)}{g} + \frac{p_2.(1 - \gamma/\gamma_2) + v.\gamma}{g}\right].\bar{V} = \frac{p_1 + p_2.(1 - \gamma/\gamma_2)}{g}.V_s + \frac{p_2.(1 - \gamma/\gamma_2) + v.\gamma}{g}.V \quad \ldots (1)$$

The energy of the assembly plus the work done by force f in lifting weight $p_2.(1 - \gamma/\gamma_2)$ from A to B, is equal to the sum of the energies of 1 and 2 assuming that they travel freely:

$$\left[\frac{p_1 + p_2.(1 - \gamma/\gamma_2)}{g} + \frac{p_2.(1 - \gamma/\gamma_2) + v.\gamma}{g}\right].\frac{\bar{V}^2}{2} + p_2.(1 - \gamma/\gamma_2).\Delta H = \frac{p_1 + p_2.(1 - \gamma/\gamma_2)}{g}.\frac{V_s^2}{2} + \frac{p_2.(1 - \gamma/\gamma_2) + v.\gamma}{g}.\frac{V^2}{2} \quad \ldots (2)$$

Equation (1) gives the velocity V and equation (2) the correction ΔH for depth H. After dividing it by V_s and p_2, we obtain from equation (1)

$$\frac{V}{V_s} = \frac{(N_1 + N_2).\bar{V}/V_s - N_1}{N_2} \quad \ldots (3)$$

$$N_1 = \frac{p_1}{p_2} + 1 - \frac{\gamma}{\gamma_2}$$

$$N_2 = 1 - \frac{\gamma}{\gamma_2} + \frac{v}{p_2}.\gamma$$

Similarly from Equation (2)

$$\frac{\Delta H}{V_s^2} = \frac{-(N_1 + N_2).(\bar{V}/V_s)^2 + N_2.(V/V_s)^2 + N_1}{2g.(1 - \gamma/\gamma_2)} \quad \ldots (4)$$

Values of V/V_s and $\Delta H/V_s^2$ (see Fig. 3) referring to a cork-made float 30 cm. diameter and 3 cm. thick as float 1, and to a hanging sphere 15 cm. diameter made of zinc plate 1 mm. thick as body 2, each weighing 509 g. are given by:

$$\frac{V}{V_s} = 1{\cdot}396.\frac{\bar{V}}{V_s} - 0{\cdot}396$$

$$\frac{\Delta H}{V_s^2} \times 10^4 = 11{\cdot}12 + 28{\cdot}10.\left(\frac{V}{V_s}\right)^2 - 39{\cdot}22.\left(\frac{\bar{V}}{V_s}\right)^2 \text{ sec.}^2/\text{cm.}$$

Remarks

(*a*) It is advisable to use a very thin nylon filament to support the sphere, in order to avoid a second depth correction due to effect of velocity on this filament.

(*b*) Operation of 10 sets of 5 floats requires about one flying hour.

Computation of mean velocity

Drawing up the diagram of surface velocity distribution on a base $\overline{AD} = 1{,}000$ (see Fig. 4), area $ABCD$ gives the mean surface velocity U_s. Using this diagram and the observed values of V, curves of equal velocity can be drawn up, and by means of them the mean velocity U can be obtained as shown in Fig. 4.

$$U = \frac{\Sigma S_n . \frac{U_n + U_{n+1}}{2}}{\Sigma S_n}$$

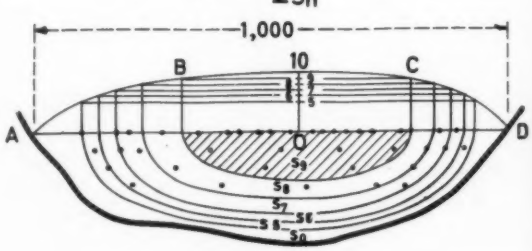


Fig. 4. Computation of mean velocity by drawing the curves of equal velocity

Trashracks and Raking Equipment

A review of the principles of design and operation of trashracks and raking devices commonly used in hydro-electric power plants

By THADDEUS ZOWSKI*

PART TWO — RAKING EQUIPMENT

TRASH accumulated on the racks of hydro-electric plants may cause considerable loss of head and curtailment of power generation, regardless of the care taken in designing the racks to minimise hydraulic losses.

The quantity of trash that collects on the racks can be minimised in many cases by the use of floating log booms consisting of logs fastened together by cables or chains and stretched across the forebay so as to intercept the drifting debris and ice before it reaches the racks. Booms may be placed diagonally to the flow to deflect most of the floating matter from the intakes toward a sluiceway or gate through which it can be passed over the dam.

Skimmer walls or trash baffles in front of racks are very useful at intakes troubled with large quantities of surface trash and sheet ice. The debris may either be skimmed off and floated into a sluiceway located parallel to the skimmer wall, or may be moved along smooth baffle walls to a sluice gate. Occasionally, so-called skimmer racks with widely spaced bars extending several feet down into the water from a service bridge or deck in front of the main racks are used to retain large floating drift and to prevent its interfering with the operation of mechanical rakes.

At some intakes, light floating trash is diverted from the racks by the use of water jets from spray nozzles. The spray-nozzle systems are most effective in installations where part of the flow bypasses the intake and is available for floating the trash downstream.

Removal of trash that has accumulated on the racks of hydro-electric stations is accomplished in most cases by raking. In the past, trashracks were usually cleaned manually by hand raking as illustrated in Fig. 9. At present, hand raking is performed only at small low-head plants or at those larger ones where very little raking is necessary and the raking depth does not exceed 15 to 20 ft. At large hydro plants with deep racks, it is practically impossible to remove trash to a sufficient depth by hand raking. Apart from that, their large rack areas would require excessive amounts or relatively uneconomical manual labour. Consequently, in large modern hydro-electric stations trash is usually removed by mechanical rakes.

Hand Rakes

Trash rakes for manual cleaning of racks usually consist of a metal raking head, wide enough to cover about an 18 in. width of rack bars, attached to a long handle. The rake teeth are spaced to fit between the rack bars and curved upward at the back to form a basket for retaining the trash. Guard bars near the ends of the teeth limit their penetration into the trashrack and prevent interference with the rack-bar spacers. Raking heads are made of mild carbon steel or of stainless steel and are usually of welded construction.

Hand trash rakes are available with solid, tubular, or laminated wood handles in lengths from about 8 to 23 ft. Rakes with special lightweight hollow handles have been devised for applications requiring long handles. The buoyancy of the hollow handle reduces the effort required in raising the rake and

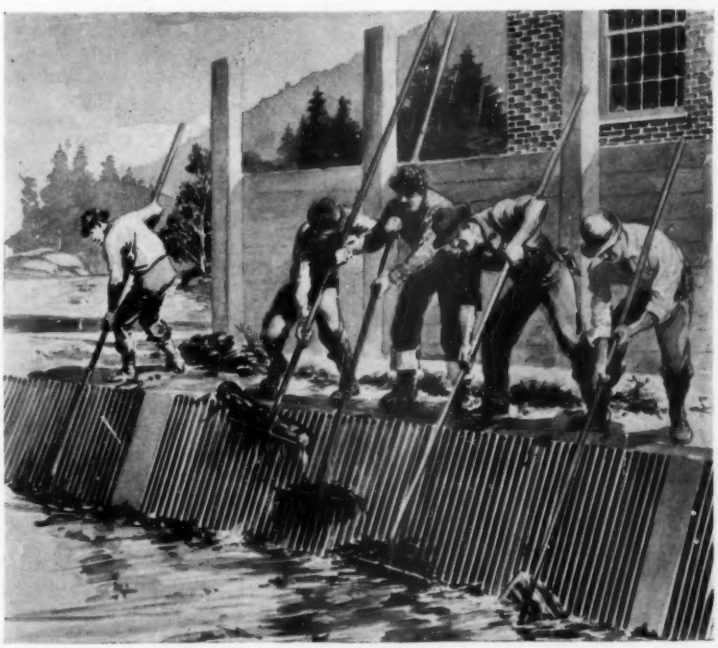


Fig. 9. Hand raking of trashracks as commonly performed in the past

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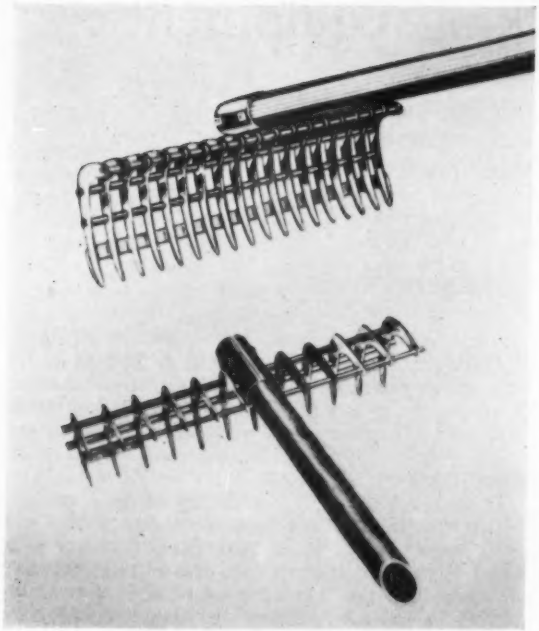


Fig. 10. Lightweight hand rakes. (Photo courtesy of Rodney Hunt Machine Company, U.S.A.)

trash. Fig. 10 shows examples of good lightweight hand rakes with stainless-steel raking heads.

Operating Principles of Mechanical Rakes

Many types of mechanical rakes and raking machines have been devised for efficient cleaning of trashracks. Most of them operate on the principle of lowering a raking element in front of the trashracks, then raising it along the rack bars so as to remove trash from them and lift it to a point from which it can be unloaded. The rakes are usually lowered and raised by motor-driven hoisting mechanisms using steel cables.

Mechanical rakes have been built for vertical travels of up to 180 ft., but a limit of about 100 ft. is considered good practice. Longer travel required for deep trashracks necessitates the use of unusually large cable drums on the hoist to avoid overlap of the cables.

For proper functioning of mechanical rakes, the velocity of flow approaching the trashracks should not be excessive, preferably not over 4 to 4·5 ft. per sec. Higher velocities may lead to operating difficulties and require special and more expensive rake construction.

To permit the use of mechanical rakes, the trashracks must be properly installed and kept in good alignment. The rack bars must be straight, parallel, and equally spaced. Trashracks consisting of several sections mounted one above the other in guides, must be aligned so that each rack bar is directly above the lower one, within not more than about $\frac{1}{8}$ in. deviation.

The two main types of power-operated mechanical rakes are the so-called unguided and the guided rakes. Each type has its advantages and limitations.

Unguided Mechanical Rakes

Mechanical rakes which operate without special fixed guides have wide-face wheels which travel directly on the rack bars and keep the raking element at the proper distance from the racks. Raised flanges on the wheels provide partial guidance in the transverse direction. The rakes depend on their weight, inclination of the racks, and the flow of water to hold them against the racks. A trashrack inclination of at least 12° and preferably 15° from vertical is desirable, but unguided rakes of special design with back plates for utilising the pressure created by the flowing water have been developed for satisfactory operation on vertical trashracks.

An operating advantage of unguided rakes is their ability to ride down over obstructions when descending. They are not restrained from leaving the racks when a stubborn obstruction is encountered, or from passing on either side of it and then working it free during the raking movement. The rakes can also serve as a grapple for removing unusually large debris. However, the lack of positive guidance may become a disadvantage in cases where the rake is subjected to strong transverse flow currents, as may occur at trashracks which are placed parallel to the main stream flow. Although proper design of intakes should prevent cross-flows, which greatly increase trashrack head losses, occasionally transverse flows cannot be avoided entirely. In such cases, if the rake is suspended on long cables because of deep trashracks and the racks are vertical or nearly vertical, an unguided rake may tend to be dislodged or even overturned by a strong cross-flow which may occur during flood conditions.

The cost of an unguided rake installation is usually lower than that of a guided rake, because it does not require the fixed guides that are needed for the latter, and the width of the rake can usually be made smaller. The width of an unguided rake is not dictated by the trashrack span, but can be kept to the minimum required for effective handling of the trash. The size of unguided rakes is determined primarily by the amount and nature of the trash, and by the total area of trashracks to be cleaned. Partial span rakes approximately 6 ft. wide are very satisfactory for small and medium size intakes with ordinary trash conditions. For larger intakes, rakes 8 to 12 ft. wide are preferable.

Unguided rakes are not well suited for some applications where the trashracks terminate at the top of the intake opening and do not extend all the way up to the operating deck. This may occur in deep intakes with removable rack sections mounted in guides. In such cases, removable metal or wooden apron panels extending from the top of the racks to the deck are usually needed to prevent the trash from falling from the rake as it travels to the unloading position.

A good example of an unguided rake is the Leonard type trash rake which is widely used in America. Fig. 11 shows this type of rake operating on an inclined trashrack. The rake shown is 6 ft. wide, the smallest of several standard sizes available.

The Leonard rake has a series of teeth arranged in a row on a tubular axle capable of rotating through an angle of about 90° and mounted in a frame with wide-face wheels at each end. When the rake is descending, the teeth tilt up parallel with the

face of the rack bars and pass over the trash so as not to push it down to the bottom. When the rake is being raised, the teeth take a raking position perpendicular to the rack bars and penetrate approximately ¾ in. into the spaces between the bars, raking the trash and bringing it up to the unloading position. The rake teeth rotate to the proper position without approaching either extreme of rake travel. This often speeds up removal of surface trash.

In the original Leonard rake designs intended for inclined racks only, the tilting of the teeth was controlled by a special mechanism mounted in the wheels. In later designs developed for use of Leonard rakes on vertical racks, the tooth rotation is controlled by levers attached to a cable sheave trunnion. This provides positive control from the hoisting motion with the use of a single-drum hoist.

Leonard rakes normally have 20 in. diameter wheels with raised flanges. The raised flanges, apart from providing lateral guidance for travel on the racks, prevent the teeth from touching the apron surface when the wheels leave the racks and proceed on to the flat surface. Wheels larger than 20 in. are sometimes used where large trash is prevalent. In cases where a single rake is to be used on several trashracks with unequal spacing of rack bars, the rake teeth are made shorter than usual so they do not enter into the bar spaces, and the wheels are provided with smooth wide faces.

Near the end of its upward travel, a loaded Leonard rake is guided from the top of the racks to the unloading position by an apron which has the same slope as the racks in its lower portion and prevents loss of trash from the rake. The apron is shaped to prevent the rake teeth from moving away from its surface because of change in angularity

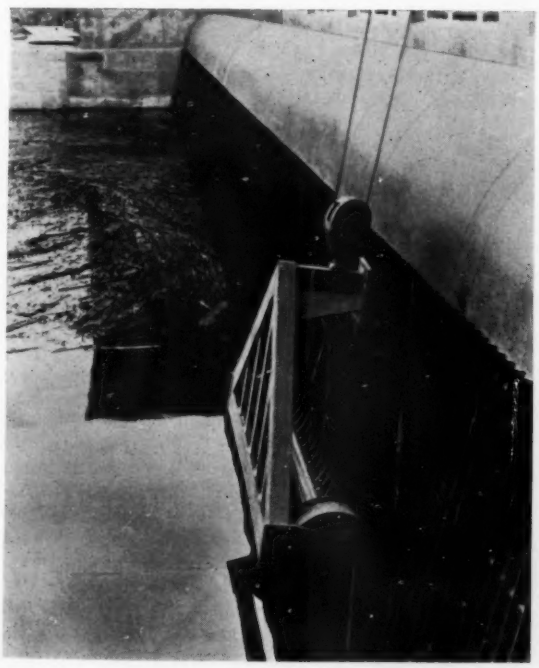


Fig. 11. Leonard type unguided rake for inclined trashracks. (Photo courtesy of Allis-Chalmers Mfg. Co., U.S.A.)

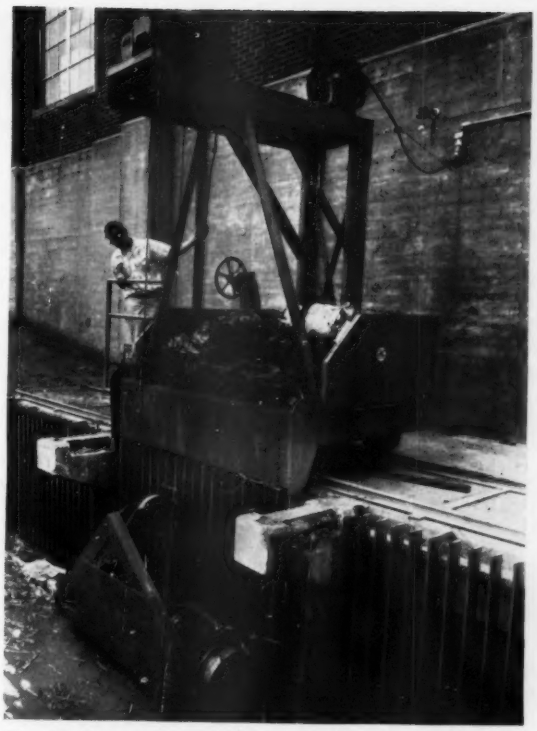


Fig. 12. Leonard type rake for vertical trashracks, with combined hoist support, trash car and apron. (Photo courtesy of Allis-Chalmers Mfg. Co., U.S.A.)

between the apron and hoisting cable. The apron also supports the rake when it is traversing along the trashrack bays from one raking position to another. Rake aprons are either combined with the hoist carriage as illustrated in Fig. 12, or are separate. When the deck is too narrow for a travelling carriage, a stationary apron extending the full width of trashracks, as shown in Fig. 11, may be used.

A Leonard rake of standard design for vertical trashracks, with hoist supported on a combined travelling carriage, trash car, and apron is shown in Fig. 12.

Another example of an unguided rake is the Glenfield plough type rake. On the downward travel, the weight of the rake causes its lower edge to plough through the trash collected on the rack bars. On the upward travel, the trash thus dislodged is caught in the basket formed by the upper part of the rake and is brought up to the surface for unloading. Fig. 13 shows a plough rake assembled in the manufacturer's shop. The rake shown is equipped with grappling hooks for handling logs and large debris.

Fig. 14 shows a view of the plough rake in the operating position, suspended from an intake gantry crane which travels above the trashracks at a tunnel inlet.

Guided Mechanical Rakes

Guided rakes require fixed guides which are usually made of steel channels embedded in the concrete walls or piers of the intake, or are attached to the rack bars. The rake is guided by rollers or sliding blocks which travel in the channel guides

located a fixed distance ahead of the racks. One of the advantages of the guided rake is that it may readily be used on vertical racks and is not affected or dislodged by strong transverse flow currents. It also has the advantage of not overriding trash, as may occur with unguided rakes under unusually heavy trash conditions. One of the most important advantages of a guided rake is its suitability for use in intakes where the trashracks do not extend up to the operating deck. A movable rake follower with an apron is lowered with the rake to the top of the racks where it remains as the rake continues to descend. On its upward travel, the rake engages the follower at the top of the racks and continues with it to the unloading level. The follower prevents the trash from falling from the rake teeth and eliminates the need for extending the racks above the top of the intake opening, or for providing an apron wall.

Guided rakes have the disadvantage that the guide channels may become obstructed or that large debris such as pulpwood can become wedged between the rake and the racks, blocking the rake, springing the wheels from the guides, or deforming the rake frame. This may occur even if the rake has a self-tripping device for releasing or opening the teeth when overloaded or caught on some fixed object. In some instances it may be necessary to send a diver down to free a jammed rake. Under severe trash conditions, guided rakes may require considerable maintenance work, but in the majority of applications, where the rakes are properly specified and designed for the type of trash conditions encountered, they perform very well.

To provide for a satisfactory installation of a guided rake, the trashracks and rake guides must be suitably aligned, parallel to each other, and the guides located the proper distance from the racks.

The width of guided rakes is determined by the design of the trashracks or the intake bays. Guided rakes have been built in widths from about 4 to 28 ft. In general, it is preferable to limit the rake width to about 16 ft., otherwise the rake becomes quite heavy if properly designed for severe duty. Full-span rakes are impracticable for very wide trashrack bays, therefore intermediate guides are used in some cases to reduce the rake width.

A good example of a guided rake is the Newport News mechanical rack rake which is used extensively in America. As seen in Fig. 15, it consists of a frame with rollers which travel in channel guides, and a pivoted raking element which is operated by levers linked to the sliding upper beam. The rake is lowered with the teeth in the open position pointing downward, parallel to the rack bars and clear of the trash. In the open position, the clearance between the teeth and the rack bars is about 15 in. The pivoted raking element is purposely unbalanced so that it opens of its own weight. As the rake reaches the bottom of the racks, the mechanical action of the hoist closes it so that the teeth project ½ to 1in. into the rack-bar spaces. It then rakes the trash from the bars as it is hoisted.

The Newport News rake requires a hoist with three cables: two outer hoisting cables and one in the centre for lowering. The hoist has a drum shaft with two outer drums fixed to it and a centre drum which can rotate part of a turn relative to it. The drums are connected through suitable gearing to the operating motor and are equipped with brakes. By applying a brake to the lowering drum and permitting the other drums to rotate a part of a turn, utilising the weight of the rake, the sliding beam is lowered, permitting the teeth to open. Then all three drums rotate and the rake is lowered until it reaches the bottom of the racks. The two outside cables then raise the sliding beam, causing the rake to close, and lift the rake to the unloading position. A clutch permits the rake to be lifted with the teeth in the open position through part or all of its travel if necessary, or when desirable to avoid overloading and automatic tripping. The hoisting and lowering speeds are approximately 30 to 35 ft. per min.

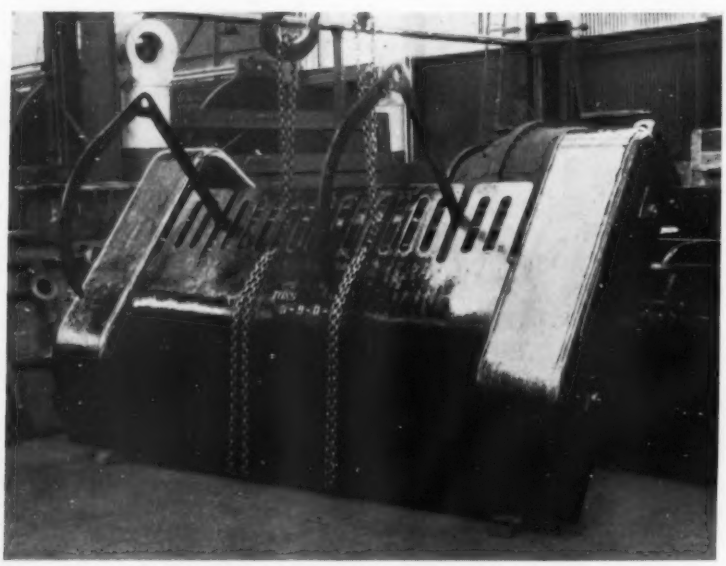


Fig. 13. Glenfield plough trash rake. (Photo courtesy of Glenfield & Kennedy Ltd., Scotland)

Rake Hoists and Carriages

Mechanical rakes are usually operated by hoists designed specially for the purpose. Some simple unguided rakes may be operated satisfactorily by ordinary intake gantry cranes, monorail hoists, or other available hoisting devices, but the larger and more effective raking machines have special hoists mounted either on independent structural-steel supports designed to suit the intake deck, or on the intake gantry crane structure. The independent hoist supports are either stationary structures or travelling carriages designed to receive the rake for unloading the rakings. They normally include an apron over which the rake travels from the racks to the unloading position. For guided rakes, the hoist support also incorporates rake guide extensions.

The hoisting machinery is usually mounted above the rake

unloading position and operates the rake by means of wire ropes or cables. Rake hoists use from one to four cables, depending on the rake design. The cables may be of steel, bronze, or stainless steel; the latter being recommended for operation in corrosive waters or seawater. The hoist usually consists of one or more cable drums, reduction gears, electric motor, brakes, and electrical control equipment. Hoisting and lowering speeds from 25 to 35 ft. per min. are commonly used. Slower speeds are often used for larger rakes and in some designs a slower speed is used for hoisting than for lowering. Because of the slower speed of the larger rakes, sometimes a smaller rake will clean almost as much area as the large rake by making more passes in the same time, the difference resulting mainly from the unloading time.

Where only one rack width is to be cleaned, the hoist support can be permanently fixed to a deck or wall. At larger power stations where the rake usually serves several bays of trashracks arranged either in line or in a large circular arc, the hoist is mounted on a travelling carriage equipped with flanged wheels which travel on rails. The carriage should be equipped with rail clamps and the downstream rail should be adequately anchored to prevent accidental overturning of the carriage in the event of overloading of the trash rake. The carriage is propelled by a hand-operated or motor-driven traversing mechanism. At least two of the carriage wheels should be connected for driving. If a traversing motor is used, it is desirable to interlock its circuit with that of the hoist motor, to prevent moving the carriage when the rake is lowered. Carriages for guided rakes are provided with centring devices for aligning them with the fixed rake guides. Some means for accurate spotting are desirable on all travelling carriages, and a manually operated brake is very useful in controlling their movement and in preventing drifting. The rake hoist carriages may also include a hoist for lifting trashrack sections or stoplogs.

Where the deck space is insufficient for a travelling carriage and the racks can be served satisfactorily by a single unguided rake, it may be desirable to operate the rake by a monorail hoist travelling on a rail supported from a wall or other structure along the deck. This arrangement, when used with a standard electric monorail hoist with hand chain traversing mechanism, provides one of the least-expensive installations.

If several individual guided rakes are used in adjacent bays because of unequal width of bays or different rack-bar spacing, the hoists should have individual motors rather than be coupled into sets using a single motor, so that a motor failure does not render more than one hoist inoperative.

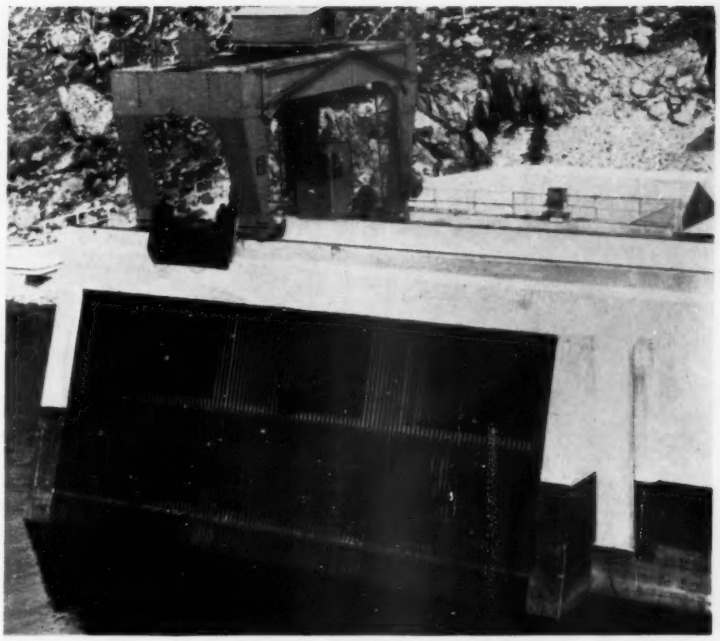


Fig. 14. View of a partial span plough rake installation. (Photo courtesy of Glenfield & Kennedy Ltd., Scotland)

Rake Unloading and Trash Disposal

Several methods of unloading trash from mechanical rakes are in use. In many installations, unloading by manual raking is the most satisfactory method, because of the complex nature of trash and the tendency of branches and some types of debris to become entangled in the rake. One man can usually operate the mechanical rake and unload it manually. If the trash is relatively small (largest dimension not much greater than about one foot), unloading by hand raking presents no great difficulty.

Some raking machines have a device called an automatic sweep which pushes the trash off the rake teeth when the rake reaches its unloading position. The device is usually operated by cams and levers. Sweeps are very useful where heavy runs of light trash such as leaves, weeds and twigs occur, but are less satisfactory for heavy debris such as logs or tree limbs.

Other raking machines are designed to dump their trash load automatically by opening their rake teeth or tilting a trash container to a dumping position when the rake reaches its uppermost position. An example of a self-dumping log-grapple type trash rake of recent design is shown in Fig. 16.

Disposal of rakings from a rack-cleaning machine is accomplished either by sluicing or by hauling away. For disposal by sluicing, the hoist support is usually provided with a hopper which guides the trash into a sluice channel below it. Disposal by carting away is accomplished either by using a combined hoist carriage and trash car, or by using a separate trash car or truck. Separate trash cars or trucks are advantageous where a wide expanse of racks is to be cleaned, because they eliminate the necessity of moving the entire hoist carriage with rake each time the

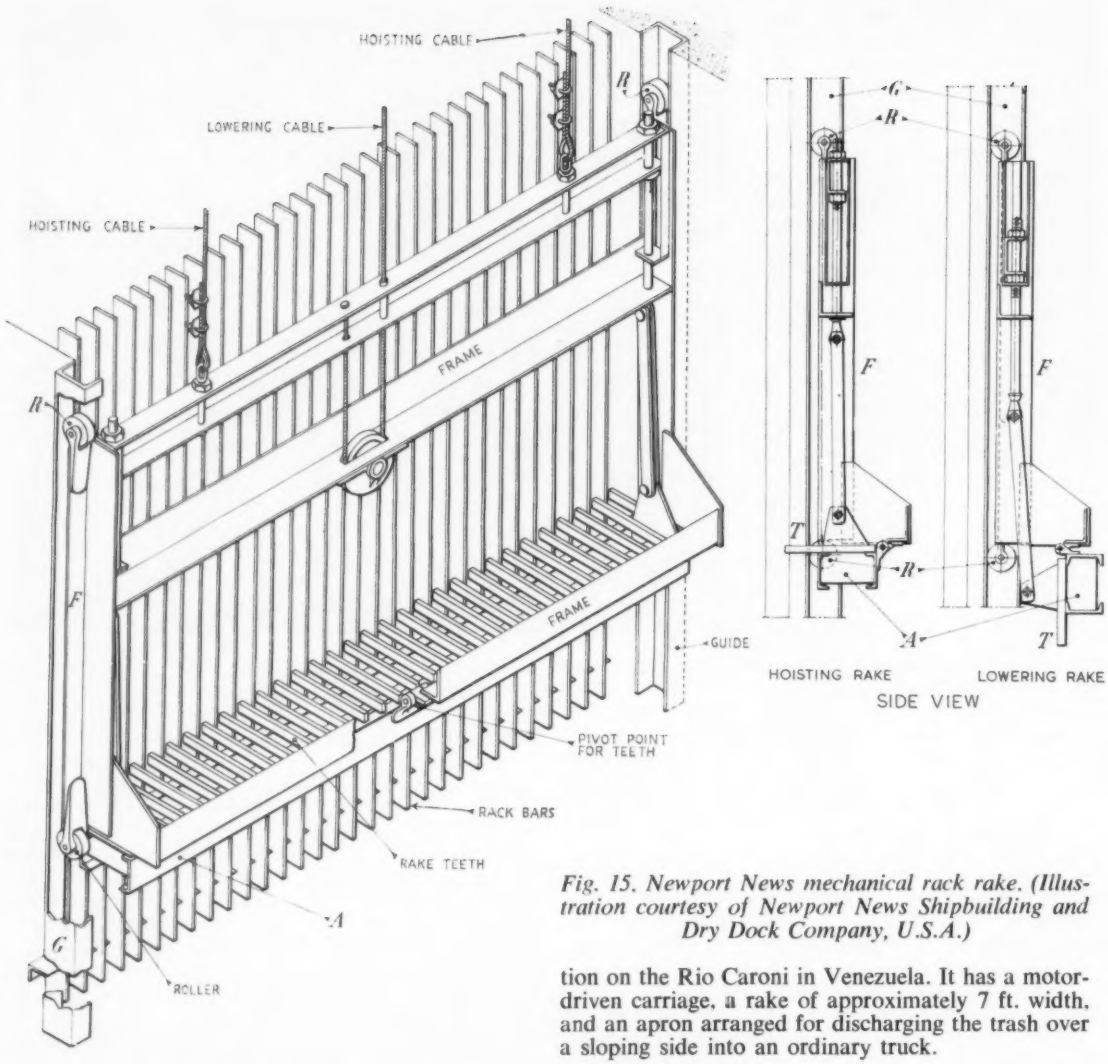


Fig. 15. Newport News mechanical rack rake. (Illustration courtesy of Newport News Shipbuilding and Dry Dock Company, U.S.A.)

trash car is to be emptied. Some trash cars are equipped with flanged wheels and travel on rails; others have wheels with rubber tyres. A hinged door at one end of the car facilitates removal of the trash when the car reaches the end of its travel, which should preferably be near a sluice gate or a burning rack. Raking machines designed to discharge the trash directly into an ordinary motor truck offer certain economies and operating flexibility. The use of a truck permits hauling the trash to any place suitable at the time.

An example of a raking machine with travelling carriage designed for discharging the trash either directly into a truck which is driven under the machine, or into a special container which is hung under the machine for loading and hauled away on a flat car or truck for emptying, is shown in Fig. 17. This machine, with a 9 ft. wide rake, was built for the Ybbs-Persenbeug power station on the Danube river in Austria.

Fig. 18 shows the shop assembly of a raking machine recently built for Macagua No. 1 power station on the Rio Caroni in Venezuela. It has a motor-driven carriage, a rake of approximately 7 ft. width, and an apron arranged for discharging the trash over a sloping side into an ordinary truck.

Types of Rake Teeth

To function successfully, mechanical rakes must be equipped with the proper raking element or teeth for the prevalent type of trash. Round and pointed teeth, as used on many unguided rakes, are satisfactory for common trash and help the rake dig into debris at the bottom of the racks, into floating rafts of debris, or submerged logs.

Special slotted teeth or triple bar teeth are desirable for removing string-like debris, filamentous algae, or similar aquatic growths that wrap themselves around rack bars. These close-fitting teeth require that the trashracks be fabricated and installed to close tolerances. Triple bar teeth consist of a centre tooth which is in line with the rack bar and two side bars which project into the spaces on both sides of the rack bar with small clearance, so they have the effect of scraping off debris wrapped around the bar. A rake equipped with triple bar teeth is shown in Fig. 19.

Grappling teeth and log hooks are used for the removal of large debris and logs. Log hooks are effective in removing relatively short and straight logs that

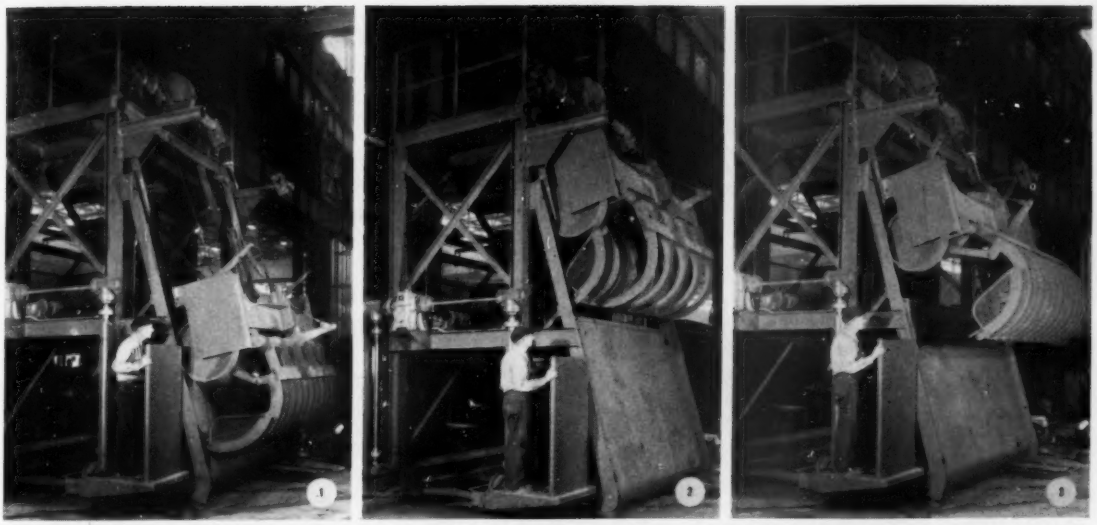


Fig. 16. Self-dumping trash rake in three typical operating positions: 1. Rake rising over apron to unloading position. 2. Rake dumping by tilting trash container. 3. Rake starting to descend. Container returned to normal position and rake teeth swung out to provide approximately 30-inch clearance. (Photo courtesy of Allis-Chalmers Mfg. Co., U.S.A.)

are lodged approximately horizontally against the racks. However, a few branches on the log or a cross arm attached to a simple timber will tend to limit the effectiveness of log hooks. Debris of this type is often handled more effectively by the use of lifting tongs. A desirable arrangement for the removal of bulky debris and logs is obtained by the use of lifting tongs operating on a jib boom mounted on the carriage of a raking machine. An example of this is seen in Fig. 20 which shows the raking machine of the Prutz-Imst power station in Austria. This machine is equipped with a heavy-duty unguided-type rake and a swivel-mounted outrigger with lifting tongs.

Rakes with special large curved teeth have been built for handling certain types of large debris. For example, the teeth of the self-dumping rake shown in Fig. 16 were designed to pick up floating barrels of sizes up to 30 in. in diameter.

Special rake teeth have also been designed for removing ice by breaking the surface ice on lowering the rake and bringing it up on the lifting stroke. However, the use of mechanical rakes for ice removal is quite limited.

For cleaning closely spaced rack bars, a rubber wiping strip in some cases is more practical than teeth. A metal wiping strip is used sometimes for heavier-duty applications.

Effectiveness of Mechanical Rakes

Most of the standard commercial mechanical rakes and special custom-built raking machines perform very well under the trash conditions for which they have been designed. Their cost is relatively small compared to the revenue value of the increased power generation they afford by keeping trashrack losses to a minimum. In some instances the provision of a mechanical rake in the original design of a power station also permits some economies in rack design through a reduction in rack-design loads.

Mechanical rakes normally require only one attendant for their operation. Under ordinary trash conditions one man per shift operating an adequate mechanical rake may readily keep the racks clean for about 10 to 15 average size turbine intakes. However, since trash conditions vary not only from site to site, but may also vary drastically from season to season, cleaning of trashracks may at times be a difficult problem to overcome with mechanical raking devices.

The main difficulty in assuring successful applica-

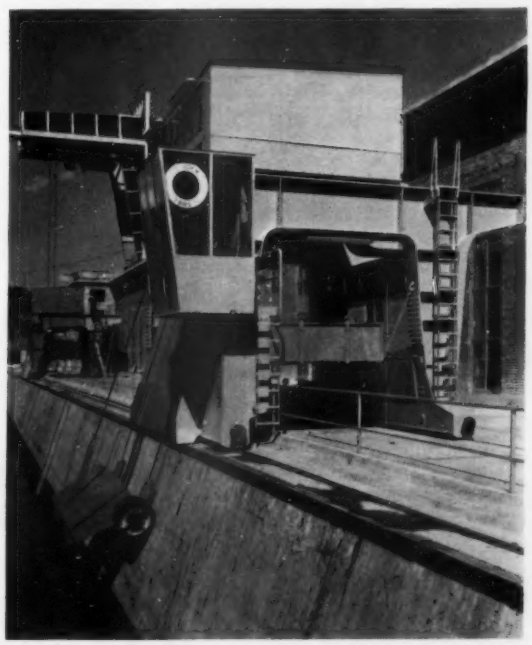


Fig. 17. Trash raking machine with detachable trash container. (Photo courtesy of Waagner-Biro A.G., Austria)

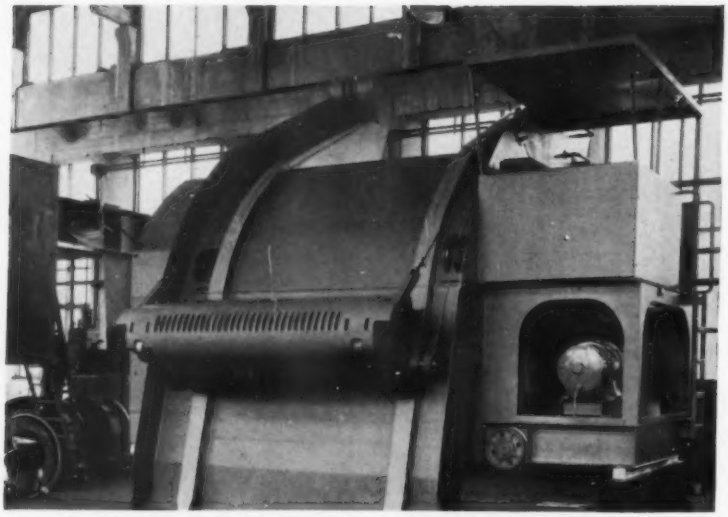


Fig. 18. A raking machine arranged for discharging trash into a truck. (Photo courtesy of Waagner-Biro A.G., Austria)

tion of trash raking machines seems to be in properly specifying the type and quantity of trash to be handled. The amount of trash to be removed is often underestimated, resulting in the installation of an underdesigned raking machine. There may also be a tendency among some designers to make the mechanism unnecessarily complicated. These factors will usually result in excessive maintenance requirements.

Maintenance of Mechanical Rakes

Mechanical raking devices require adequate maintenance to keep them in good operating condition. This includes lubrication of moving parts, painting for protection against corrosion and repairing of damaged parts, especially straightening of bent rake teeth or log hooks. Wire-rope cables require greasing and inspection at regular intervals. Sheave grooves should be examined from time to time for worn spots which could shorten the life of the cable. Motors, gears, brakes, and all moving parts require periodic inspection and maintenance, especially parts exposed to weather.

Other Trash-Removal Devices

In view of the normal operating limitations of mechanical raking devices and their maintenance requirements, particularly under severe trash conditions or under conditions resulting from misapplication, some plant operators prefer to use a more simple and rugged type of rake which can be operated by an ordinary crane.

An example of a large crane-operated trash rake is shown in Fig. 21. This type of rake is being used successfully at several hydro-electric stations of Topoco, Inc., and Yadkin, Inc., wholly owned subsidiaries of the Aluminum Company of America. The rake shown placed on an intake deck is used at the Chilhowee hydro station on the Little Tennessee River, U.S.A. It has a number of flat bars spaced to match the rack-bar spacing and curved to form a large basket for collecting the trash as the rake is pulled up along the face of the trashracks. The raking ends of the bars are connected by a round guard bar which limits their penetration into the rack-bar spaces and prevents interference with the rack bracing. The rake is suitable for handling a wide variety of debris.

One of the earlier types of mechanical raking devices deserving mention is the continuous-chain-type rake with steel raking fingers or teeth mounted on horizontal bars which are attached to travelling chains. The chains operate over sprockets and are driven by an electric motor. The raking teeth enter the bar spaces at the bottom of the racks and travel upwards at a speed of about 20 ft. per min., removing the trash and bringing it up to a deck where it is automatically dumped. Rakes of this type perform quite well in shallow intakes, especially if supported independently of the racks so that the rake may readily be lifted out for repairs. However, experience has shown that freezing conditions and sometimes a heavy snowfall may put this type of rake out of operation.

At some low-head rack installations troubled with considerable submerged trash, compressed-air bubbler systems of the type used to prevent surface ice formation have been found useful in reducing the task of cleaning the racks. The upward current induced by bubbles rising from perforated air pipes or nozzles at the bottom of the racks tends to dislodge trash from

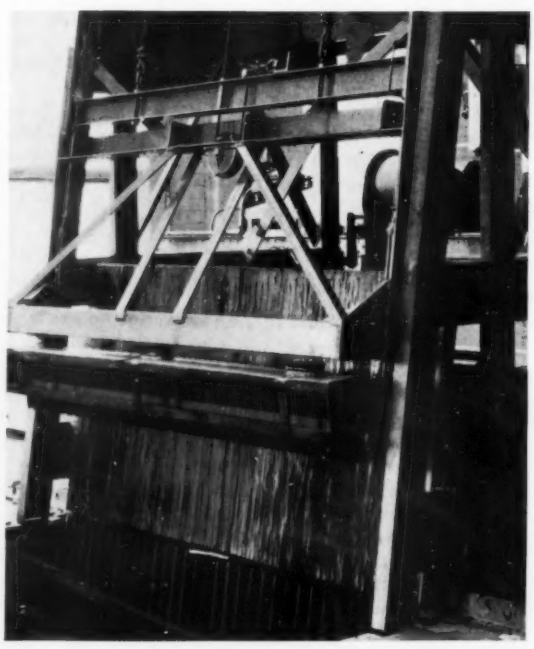


Fig. 19. A guided rake with special triple bar teeth for removal of aquatic growths. (Photo courtesy of Newport News Shipbuilding and Dry Dock Company, U.S.A.)

the lower parts of the racks and carry it to the surface from which it may be passed into a sluiceway. Bubbler systems are effective if the approach velocities are low and fairly constant. However, they should be designed with care to avoid their affecting turbine flowmeters.

Compressed-air systems are also used sometimes at deeply submerged intakes for occasional cleaning of the racks. An example of such a system is found at the Norris hydro plant of the Tennessee Valley Authority, where the trashracks are located approximately 150 ft. below the reservoir level. Air pipes have been provided around the periphery of the semicircular trashrack structures. The pipes have $\frac{1}{8}$ in. holes spaced 6 in. apart with alternate holes at 15° and 30° from the vertical, for blowing the compressed air so as to dislodge the trash. The Norris trashracks, however, have not collected much trash in actual operation.

Revolving-drum-type self-cleaning trashracks have been used successfully in small turbine installations on trash-laden streams or power canals where the headwater level is nearly constant.

Where no rakes or special cleaning devices are provided, but some floating trash occasionally collects at the racks, it is good practice to remove it before it has a chance to become waterlogged and sink to the bottom. If the velocity of flow through the racks is not very high, such trash can be moved on the water surface along the face of the racks to a convenient point of disposal such as a sluice gate. If it is undesirable to pass large debris over the dam because of downstream plants, the debris is usually towed to a suitable location on the shore where it is placed on a pile and burned. At large hydro stations it is advisable to have a diver inspect the trashracks at intervals of several years to loosen and remove any trash that may be lodged in them.

At intakes equipped with gantry cranes for handling gates, it is good practice to provide a jib hoist attachment on the crane for operating a clamshell bucket or log tongs for removal of large debris and logs. A jib hoist facilitates the use of various lifting devices that may be useful in special cases. Among these is a basket rake

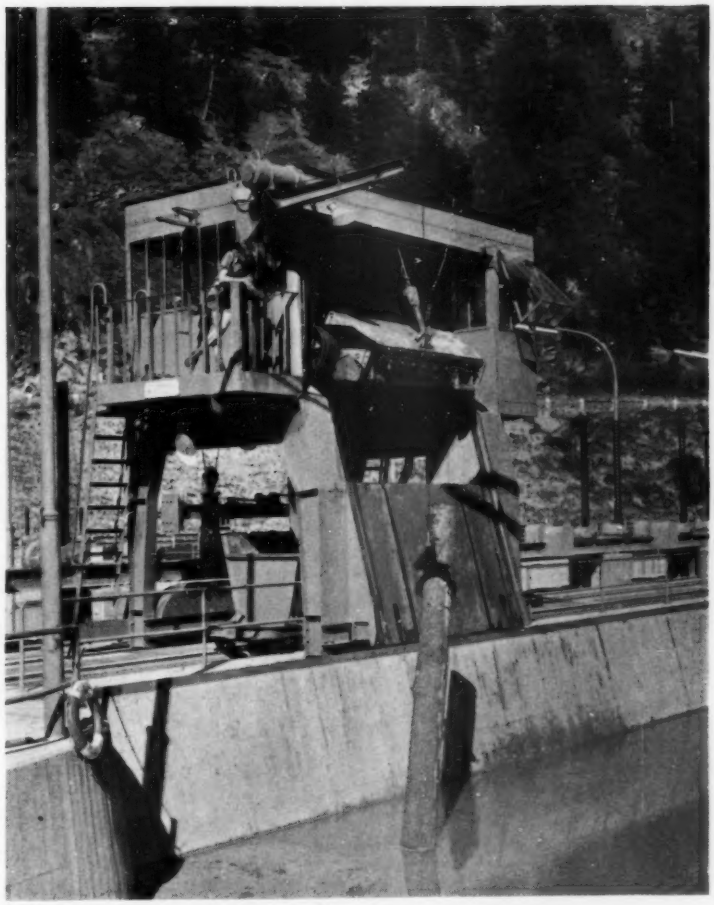


Fig. 20. Rack raking machine equipped with lifting tongs on a jib boom. (Photo courtesy of J. M. Voith, G.m.b.H., Germany)

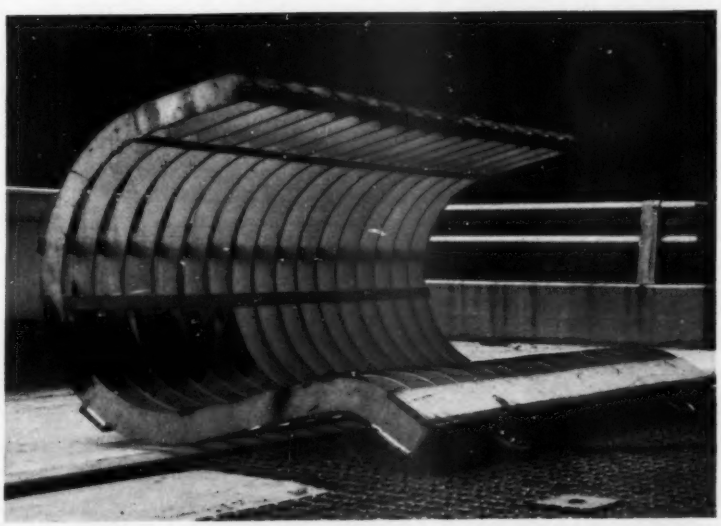


Fig. 21. Large crane-operated trash rake. (Photo courtesy of Aluminum Company of America, U.S.A.)

shaped somewhat like a candelabra and used for removing submerged logs. It has a number of replaceable and expendable teeth around its periphery, mounted loosely to permit freeing and recovering the rake in the event one of more teeth become firmly lodged in a log that is too heavy to lift, or if the rake becomes caught on some large object.

In general, regardless of the method of trash removal, intakes should be so designed as to provide sufficient access to the racks, if possible. At intakes where large floating debris frequently finds its way to the racks, it is desirable to provide ladders on the side walls or piers in front of the racks, to enable an attendant to reach the debris which cannot be lifted by a rake or other device and to attach a rope for removing it by a crane.

New Power Vane Compressor

A new oil flooded rotary Power Vane compressor of 260 cu. ft. per min. capacity at 100 lb. per sq. in. has been introduced by the Consolidated Pneumatic Tool Co. Ltd., 232, Dawes Road, London, S.W.6. A feature of this compressor is the new styling that has been adopted. This new compressor has been introduced to meet the demand for a unit between the existing sizes of 210 and 365 cu. ft. per min., and uses the Power Vane principle in which an eccentric rotor, equipped with sliding vanes, is employed to compress air in a cylindrical chamber into which oil is pumped as a fine spray, the oil serving to lubricate and seal clearances and to cool the air at the time of compression. The 260-RO-2 is a two-stage in-line compressor, powered through a safety friction drive by a six-cylinder Leyland U.E. 375 diesel engine.

Positive alignment of this engine and the first-stage compression casing is made by a tandem piece which supports the casing and is bolted to the engine flywheel housing, an interstage tandem piece mounting the second stage. The rear end of the second-stage casing is closed by the oil-pump housing and cover, a headplate enclosing the front end. To prevent loss of oil and to protect the shaft bearings from dirt, a rotary shaft seal is located at the drive end of the compressor. Both first- and second-stage casings are of the same diameter, the second-stage casing being of shorter length. Each encloses a vane-type rotor which carries eight blades of non-metallic composition, the rotors being mounted on shim-adjusted tapered roller bearings at each end, thus enabling positive rotor positioning between casing headplates.

The direct-injection four-stroke six-cylinder Leyland U.E. 375 diesel engine which powers the compressor is water cooled and is of the overhead-valve type. The continuous 12-hour rating of the engine for this duty at a governed speed of 1,800 r.p.m. is 82 b.h.p.

Wire-Braided Pneumatic Hose

The range of Goodyear industrial hoses has been increased with the introduction of Wingflex high-pressure wire-braided hose. Wingflex is made in 1 or 2 braid constructions for use with machine and pneumatic tools, earth-moving equipment, compressed-air units and similar industrial applications. It is supplied in bore sizes ranging from $\frac{5}{32}$ in. to 2 in. with either reusable or swaged couplings. (The reusable coupling is invariably supplied with 1 braid hose—i.e. where pressures are relatively low—and

swaged couplings with 2 braid hose or where excessive flexing occurs.) The reusable couplings include male and female couplings as well as elbow couplings manufactured with either 45°, 60° or 90° angles.

The hose consists of a seamless and oil-resistant synthetic-rubber tube with a smooth bore, and is designed to operate throughout a range of pressures varying from 600 to 4,000 lb. per sq. in. in the 1 wire braid construction and from 1,000 to 5,000 lb. per sq. in. in the 2 wire braid construction. It is reinforced with high-tensile steel wire which is uniformly braided over the lining. The cover is made of synthetic-rubber compound (resistant to abrasion, oil, light and flame) and the complete hose is uniformly vulcanised and concentric throughout its length.

Wingflex will be supplied in either 60 ft. lengths uncoupled or in lengths coupled either with reusable couplings or the swaged-type couplings. Every assembly is tested individually. The couplings are designed to withstand pressures well in excess of the burst pressure of the hose.

New Model Dominion Shovel

A new 3 cu. yard shovel of completely new design and incorporating the latest features of power crane and shovel practice is being introduced by Dominion Engineering Co. Ltd. Known as the Model 600, it is completely designed and engineered in Canada and is now in production at the Dominion Engineering plant in Montreal.

This machine is similar in deck layout to the 1½ cu. yard Model 480 and the 2½ cu. yard Model 550, both of which are completely new designs and were introduced recently. The two-main-shaft machinery arrangement is designed for easy conversion of front-end attachments and low-cost maintenance, all major assemblies being quickly removable. Air controls and a torque converter are standard equipment.

As a shovel the Model 600 weighs 174,500 lb. The shovel boom is 28 ft. long and the dipper stick has an effective length of 18 ft. 8 in. The standard crawlers have an overall length of 17 ft. and can be fitted with either 36 in. or 42 in. wide tread links.

Jointing Rubber Waterstop

To join the ends of rubber waterstops where it is not convenient or practicable to use a field vulcanising unit, Tretol Servicised Limited, 2 Caxton Street, London, S.W.1, have introduced a jointing sleeve which is applied by means of a cold-cementing process.

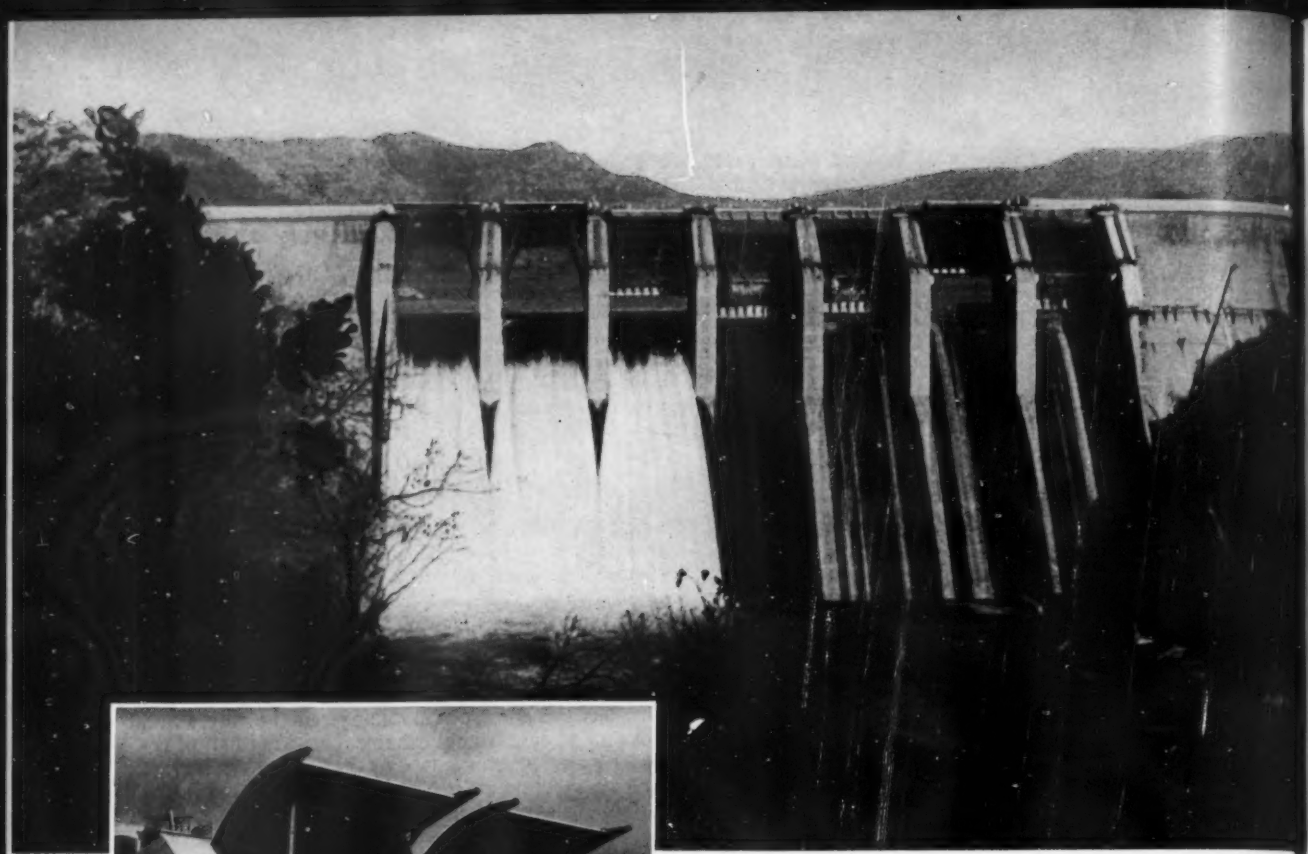
Electro-Polishing Stainless Steel

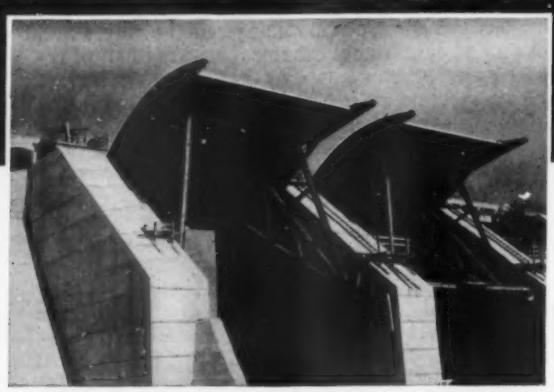
The polishing of stainless-steel fabrications, large or small, by electro-chemical means has been developed commercially by Electropol Processing Limited, Trading Estate, Farnham, Surrey. The process, which is the exact reverse of electroplating, consists of placing the fabrication in a bath of electrolyte and applying a current in a direction to remove about half a thousandth of an inch from the surface. This has the effect of smoothing out the ridges and valleys resulting from mechanical working and of removing any process film or other impurity, leaving the pure metal in a clean, polished state. The polished surface is stated to be more resistant to corrosion than the original surface because all impurities have been removed. Furthermore, the surface tends to be repellent to dirt and moisture.

The process is claimed to be much more economical than the earlier techniques of grinding and polishing, and it permits greater freedom of design because the need to arrange for access of grinding wheels and polishing tools to internal surfaces does not arise. Welded fabrications can be profitably treated, as the welds themselves are also polished.

In the early stages the process was employed for small articles only, but techniques have been developed to handle the largest fabrications likely to require polishing. Gas-turbine runners in various sizes up to about 6 ft. in diameter have been treated, and the firm sees no practical or commercial difficulty in polishing stainless-steel water-turbine runners, whether cast or fabricated, in any required size. For such large components the use of the process (which is patented) under licence would probably be the more convenient procedure.

Soil Mechanics Limited, 65, Old Church Street, London, S.W.3, have sent us a collection of pamphlets on site investigation, geotechnical processes and construction devices, used and developed by their firm. Of particular interest to readers is a combined surface density and moisture meter which has been developed in association with Dynatron Radio Limited. In principle, a probe with a radio-active source is pushed into the soil and the emitted gamma rays and slow neutrons are received by a scaled geiger tube for readings of soil density and moisture respectively. For corrosion surveys, soil resistivity measurements are taken using the Wenner four-electrode system. This is followed by a measurement of depolarising ability of the soil carried out on an iron and magnesium cell—and finally to examine the ground water for pH value, sulphate, carbonic acid, etc.





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Photos 1 and 2
7 spillway tainter gates 12 x 12 m for dam flood control

Photo 3
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Abstracts from the World Technical Press

St. Lawrence Project: Rehabilitation Work

The purpose of this paper, presented at the 73rd Annual General and Professional Meeting of the Engineering Institute of Canada in Toronto, is to review some of the major features involved in the rehabilitation programme of the St. Lawrence power project. A description of the areas to be flooded is followed by a survey of the planning work and the construction schedule. The actual field programme is discussed in ten separate paragraphs and includes, among other extensive relocations, a 39 mile double-track line between Cardinal and Cornwall, and the transfer to new towns, on Hartshorne movers and house-moving trailers, of 531 houses. Using trailers with extra dollies at rear to distribute load, a historic church was conveyed intact 15 miles away. (J. H. Jackson, *The Engineering Journal*, Vol. 43, No. 2, February, 1960, p. 67, 9 pp., 9 ff.)

Strengthening Large Concrete Gravity Dams

The author of this paper first reviews the methods hitherto in use for the strengthening of existing large concrete gravity dams. The "bonded backing-slab" method, used for strengthening and heightening the spillways of Burrinjuck dam, N.S.W., and Mullardoch dam, Scotland, calls for special measures to allow the backing slab to take up draining and cooling shrinkage before it is bonded to the original structure; otherwise shear stress sufficient to destroy the bond may arise in the joint. A fairly similar procedure called the "loose backing-slab" method, was applied to Aswan dam. Here the strengthening is provided by placing a "loose" concrete slab on the downstream face of the dam to be reinforced, and although this avoids the complicated and costly measures necessary to ensure the bond, it requires a larger volume of concrete to achieve the same degree of stability. The third method, patented by the well-known French expert M. A. Coyne in 1934, and first applied to the Cheurfas dam, Algeria, consists in placing vertical wire cables in so-called "blind holes" drilled through the wall of the dam near the upstream face from the crest into the foundation, grouting the holes for anchorage, and then tensioning the wire cables to produce stabilising compression forces on the upstream face of the dam. No provision is made in this method to minimise the high uplift forces, therefore it would be necessary to design the strengthening of the dam on the full uplift. The main advantage of the Coyne method is that it will usually prove less expensive than either of the previous two methods. In the method the author advocates, the approach to the problem of dam strengthening is different. It aims first at reducing the uplift forces under the foundation of the dam by the formation of a grout curtain and then strengthening the structure on the minimised uplift forces and the increased pressure due to heightening. The actual strengthening of the dam is achieved by the provision of tendons similar to those adopted in the Allt-Na-Lairige dam in Scotland, and placed in ducts drilled through the wall of the dam near the upstream face from the crest into the foundation; there, the tendons are placed in anchorage shafts and tensioned to produce stabilising compression forces on the upstream face of the dam. One of the principal advantages claimed by the author for his method is that it creates a normal condition of stability of the dam by eliminating the high uplift forces, and then designing the strengthening of the structure on considerably reduced uplift forces. From the economical point of view it is claimed that the method will be no more expensive than the Coyne method, and that it enables the strengthening of large concrete gravity dams to be treated as a normal reinforced-concrete job. (G. S. Boris, Department of Public Works, N.S.W. *Australian Civil Engineering and Construction*, Vol. 1, No. 6, March 1960, p. 44, 4 pp., 8 ff.).

NOTE. The above mentioned journal also contains an article by John A. Cave on "Prepakt" cast-in-place piling, which has solved some difficult foundation problems in America and Japan. Typical examples are briefly described and design criteria are outlined. (p. 53, 6 pp., 4 ff.).

Spillway Dwarfs Main Dam

Work has recently started on the final contract of Tacoma City Light's 160 MW development at Mayfield on the Cowlitz River, Washington. A photographic view of the model of the plant sharply illustrates the contrast between the narrow main arch dam, which rises 185 ft. in a canyon only 40 ft. wide, and its massive five-bay spillway section. Water reaches the four penstocks through a 860 ft. tunnel, 37 ft. in diameter, and then drops to the generators 200 ft. below the reservoir level. Elaborate accommodation is provided for the migrating fish. Those heading upriver are trapped at a barrier set up across the gorge immediately upstream of the power house erected along the right bank of the canyon, turned into a horseshoe ladder, and then raised to a flume that carries the fish into the reservoir. Fish moving downstream are trapped at the tunnel intakes, bypass the turbines by means of a skimmer device and then continue their journey. (*Engineering News-Record*, Vol. 164, No. 11, March 17, 1960, p. 25, 1 f.)

High Earth Dam in Narrow Canyon

The most remarkable feature of the Mammoth Pool hydro-electric project in the High Sierra, Southern California, is the 5 million cu. ft. earthfill dam, 830 ft. in crest length, and rising 350 ft. above the streambed, set up at a spot which, at first sight, appeared made to order for a concrete dam. Following comparative investigations of all the various types of dams, the earthfill design was found to be the cheaper by a margin of at least $1 million. The steep canyon walls dictated special care in earth placement; for this reason, all overhanging rock was removed by blasting and scaling, and the fill adjacent to the abutments was kept plastic during the construction period with additional water, to accommodate settlement without shearing. Fill material was classified for placement purposes in several categories. The tightest control was reserved for the 1·6 million cu. ft. impervious core, specification requiring at least 20% of the material to pass the No. 100 sieve. There was no convenient supply of sufficiently permeable fill for the

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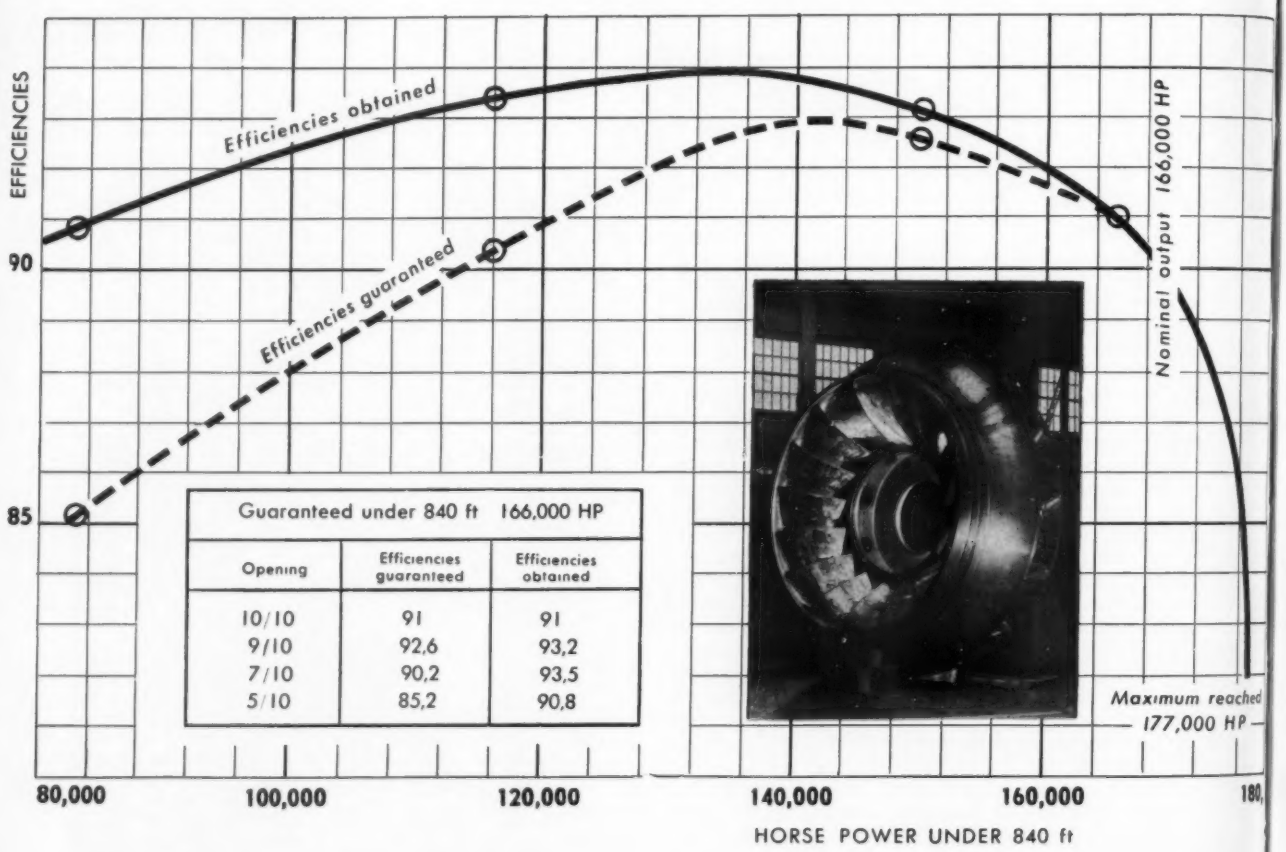

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embankment on the downstream side of the core, so a drain of coarse material was installed to intercept and carry off seepage, and prevent its entry into the relatively impervious material of the downstream shell. Since the drain system isolates the downstream half of the dam, the downstream shell could be designed as a well-drained embankment rather than with special consideration for its function as part of a dam. As a result, the downstream face has the relatively steep slope of 2 : 1. The Mammoth Pool project has been marked by fast progress and by the use of unusual methods in the construction of both its tunnels—a diversion 28 ft. horseshoe tunnel, 2,150 ft. long, which was holed through on the 77th day of a 120-day contract, working from a single heading; and a 20 ft. horseshoe power tunnel, 40,000 ft. long, running through granite and metamorphic rock of good quality. This power tunnel was driven from five headings, using four 11 drill jumbos. Here again, progress was spectacular, the contractor nearly setting a world speed record in January, 1959, by driving one heading 390 ft. in a six-day week for an average of 65 ft. a day. This project, which is now feeding into the utility's network, is the newest unit in South California Edison's Big Creek hydro-electric development, including at present eight power stations with a generating capacity of 690 MW, five reservoirs totalling 537 million acre-ft., a dozen or more dams of various types and sizes, and several tunnels and conduits, most notable being the Ward tunnel, a 13 mile bore of 15 × 15 ft. cross-section. (*Engineering News-Record*, Vol. 164, No. 14, April 7, 1960, p. 44, 5 pp., 12 ff.)

Gave d'Ossau Hydro-Electric System

This development, which is operated in the Western Pyrénées by the French State Railways, and comprises the Fabrèges, Artouste, Miègébat and Hourat plants, has recently been completed by the addition to the five horizontal-shaft 12,000 h.p. generating sets in service at Miègébat, of a new vertical-shaft 32,000 h.p. Pelton wheel, thus increasing the capacity of this power station from 40,000 to 65,000 kVA. A comprehensive description is given of the new turbine and of the installations connected with it. This addition was made possible by the harnessing of the Gave du Bitet waters, a left-bank tributary of Gave d'Ossau. The intake on the Bitet is a small spillweir 6 m. high, fitted with a flushing gate, and a stop gate at the head of the supply conduit. The water leaves the pool through a welded steel pipe, of 1·2 m. diameter, 220 m. long, which connects with a semicircular tunnel of 2 m. diameter and 2,620 m. long, designed for a discharge of 3 cu. m. per sec., and leading through a surge tank to the 660 m. long penstock designed for a maximum discharge of 4·3 cu. m. per sec. This penstock leads into the Miègébat manifold on which is also branched the Bitet generating set, so that the Pelton turbine of this set shares the supply discharged by the Artouste plant with the old generating sets, and can thus pass 7 cu. m. per sec. This Pelton wheel, designed and supplied with all its hydraulic equipment by Neyrpic, is a five-nozzle unit operating from a net head of 380 m. at 428 r.p.m. and driving a three-phase Schneider-Westinghouse alternator. All five nozzles are fed from a ring bus, the first four being on branches, and the fifth a conventional elbow nozzle. This pattern, selected after extensive laboratory tests, ensures a more uniform distribution of the discharge and lesser head losses. The stainless-steel wheel (13% chrome, 1 to 1·5% nickel) has a pitch diameter of 1,850 mm. and carries 23 buckets of special design cast in one with the rim; its housing consists of five sheet-steel sections 12 to 16 mm. thick, which were welded together on site. With the addition of the Bitet generating set, the capacity of the Miègébat plant has substantially improved—in fact, the new set alone provides the same output as three of the old sets. Besides, the Gave d'Ossau system is now in a position, at the high-water spring and autumn periods, to cope with the whole of the discharge available, and the downstream plant at Hourat can now be run to saturation point at these times. (G. Vié, *La Houille Blanche*, Vol. XV, No. 1, January–February, 1960, p. 31, 10 pp., 11 ff.)

Operating Hydro-Plants by Remote Control

Remote control has been in use for a fairly long time, but its application has practically been restricted to smaller plants. The authors of this paper survey the experience gained in Sweden in extending the method to fairly large power stations or groups of power stations, and describe how these stations operate, and how they compare with plants still operated by control on the spot. Various types of remote control are reviewed and their cost compared. At first sight, there appears to be sound reason for proceeding with the application of remote control on a wider basis. There are, however, points which are still under consideration, such as the possibility of further reducing the personnel and of doing away with the duplication of radio links, improvements in the organisation of load despatching, and the problems connected with the important question of maintenance of the remote-control equipment. Practical experience gained from larger plants in operation will provide a better knowledge of the advantages and disadvantages of remote control as a whole. (G. von Geiger, B. Nordström and A. Bergmann, *Blue-White Series of Swedish State Power Board*, No. 26, 8 pp., 8 ff.)

Electricity Production in Portugal

In the first instalment of this article, which deals with the 1951–1959 period, the rise of the permanent demand during these eight years is reviewed and this natural increase is compared with the planned increase of the means of production brought into operation to meet the demand. The advantages resulting from this gradual increase are shown not only for the permanent demand, which was covered by a capacity leaving a substantial safety margin, but also for the periodical demand which considerably increased without affecting in any way permanent requirements. Finally, attention is drawn to the advantages achieved by the various methods of operation of the primary systems, either interconnected in grids or working in pools. In the second instalment, following a general outline of the evolution of hydro-electric developments and of their equipment, an analysis of the systems adopted at Cávado-Rabagão, Zézere and Picote is given, various types of dams in service are described, and their selection explained. The problems that arose in the various schemes are set out from their initial conception to their completion. The paper ends with a survey of the economic and financial aspects applying to the various concessionary

enterprises. (A. C. Xerez, *Electricidade*, No. 13, January–March 1960, p. 21, 4 pp.; No. 14, April–June 1960, p. 209, 7 pp., 4 ff.)

Stability Analysis in Earthfill Dams

The author attempts to work out in this paper a rough approximation method for the purpose of determining the stability of the downstream bank of a drainless earthfill dam in a localised area such as the spot where seepage water leaks out of the dam. A comparative survey of the methods most frequently applied to the determination of the seepage line in earthfill dams is first made, and their results are then set against those of model tests. The Pavlovsky-Dachler method, considered the most appropriate, is selected for further computation. By this method, and proceeding with the help of Bernatzik's work from the observation of the state of equilibrium existing in a volume of earth sited on the downstream slope, the stability of the downstream bank at localised spots is subsequently analysed, taking into consideration any pervious load (rock dump) on the slope and any slight cohesion of the ground. This paper practically applies only to low and medium dams, not exceeding about 15 m., since higher earthfill dams are always provided with drains. (Rotislaw Davidenkoff, *Die Wasserwirtschaft*, Vol. 50, No. 2, February 1960, p. 38, 6 pp., 10 ff.)

Frequency Regulation in Kaplan Turbines

In this article, the authors analyse the possibility of reaching an optimum degree of frequency regulation in Kaplan turbines, due account being taken of the influence of the efficiency diagram (Hill chart) on the governing equation. In the first part of the paper, the effect of partial efficiency diagrams for constant blade angles is examined in relation to the isolated network frequency control. The parameters of regulation (best choice of governor constants, value of the integral defining governing precision, and many others) have been assessed in a great number of cases. In the second part, G. Ransford, following a short note on three parameters relating to maximum frequency disturbances after a sudden load variation, gives a numerical application of the method of analysis set out in the first part with regard to bulb units operating in an independent network. The example dealt with tends to disprove the opinion that, because of their small inertia, these units were unable to contribute usefully to frequency control. (G. Ransford and J. Rottner, Sogreah-Grenoble, *La Houille Blanche*, Vol. XIV, No. 6, November 1959, p. 762, 16 pp., 4 ff., 1 table; Vol. XV, No. 1, January–February 1960, p. 22, 9 pp., 3 ff.)

Electro-Hydraulic Governors

An account is given of the practical experience gained at the Beechwood plant of the New Brunswick Electric Power Commission with the ASEA electro-hydraulic governor described at length in WATER POWER, October, 1952, p. 396. The Beechwood development represents approximately 23% of the total generation of NBEPC system with its interconnections. The nature of the system load varies from time to time and from season to season, and an accurate and readily available method of altering governor characteristics to match system conditions is therefore highly desirable. The ease of adjustment and the possibility of operating the entire station through a single set of controls is a distinctive feature of the ASEA electro-hydraulic governor, and it was the above considerations, together with the success achieved by this governor on the large integrated Swedish systems, which led the designers of the Beechwood station to recommend it to the NBEPC. The Beechwood governors have now been in operation a year and a half, and in the light of the operating and maintenance experience of this period, it can be said that they have fulfilled all expectations. (G. H. D. Ganong and P. G. Fazzari, *The Engineering Journal*, Canada, Vol. 43, No. 2, February 1960, p. 35, 6 pp., 6 ff.)

Operating Power Reservoirs in Tropical Regions

A condensed but fairly comprehensive study is given of the behaviour of power reservoirs in tropical countries, proceeding from the practical experience acquired at the Haut Katanga plants (WATER POWER, May 1955, p. 169). These installations lend themselves exceptionally well to investigations of this nature, since they comprise two storage lakes which are essentially dissimilar in character and thus react in different ways to the effect of direct evaporation, so that their study covers a wide range of conditions. Following a short introduction, the author endeavours to establish an equation of the water budget in order to determine the various factors intervening and to explain how these factors can be measured or computed. He then stresses the importance of water budgets as a means of assessing the volume of water available in the power reservoir and, altogether, to investigate the behaviour of the reservoir. The natural phenomena likely to depreciate gradually the efficiency of power reservoirs through reducing directly or indirectly the harnessable volume of water, such as silting and floating islets of compacted weeds, are also discussed together with possible protective measures. It is obvious, concludes the author, that further investigations will be required before all the factors intervening in a water budget of this kind are ascertained with the required degree of accuracy, but even at our present stage of knowledge, water budgets supply elements of computation sufficient to enable us to determine the probable available volume of harnessable water in a given power reservoir, whatever may be its characteristics. (P. C. van Cauwenberghe, *La Houille Blanche*, Vol. 15, No. 1, January–February, 1960, p. 56, 15 pp., 11 ff.)

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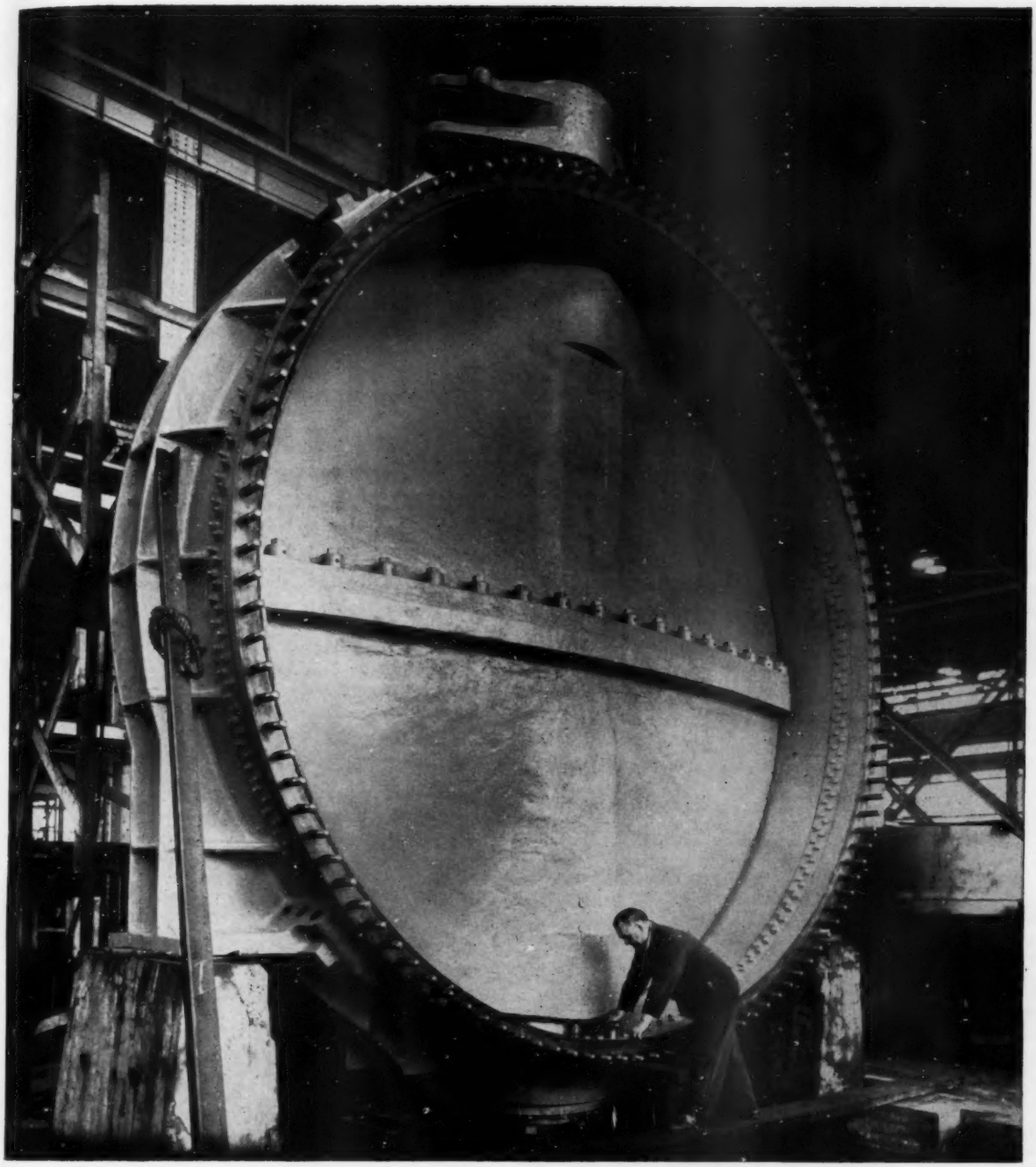

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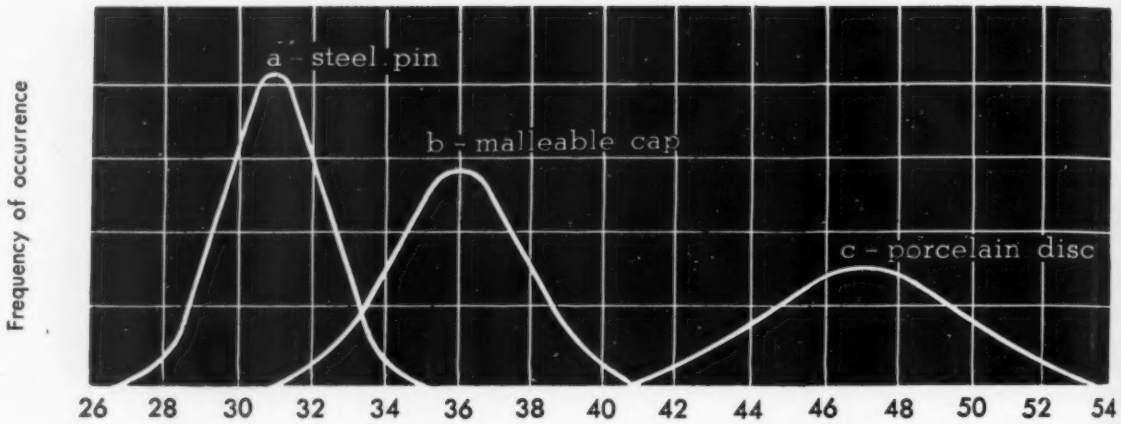
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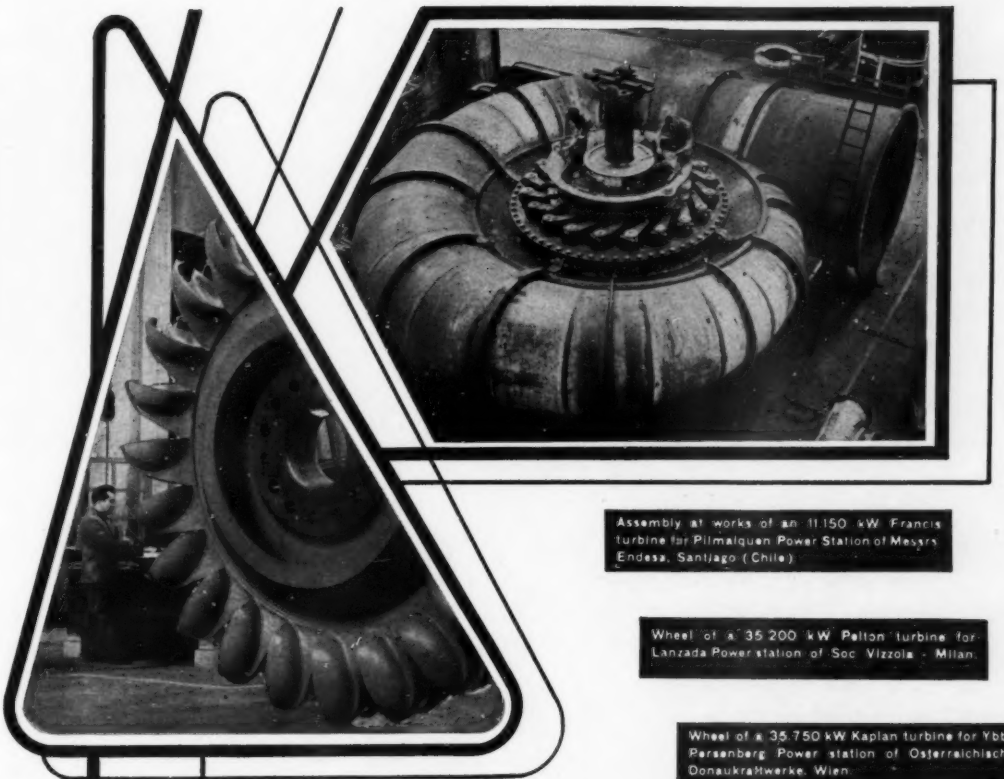
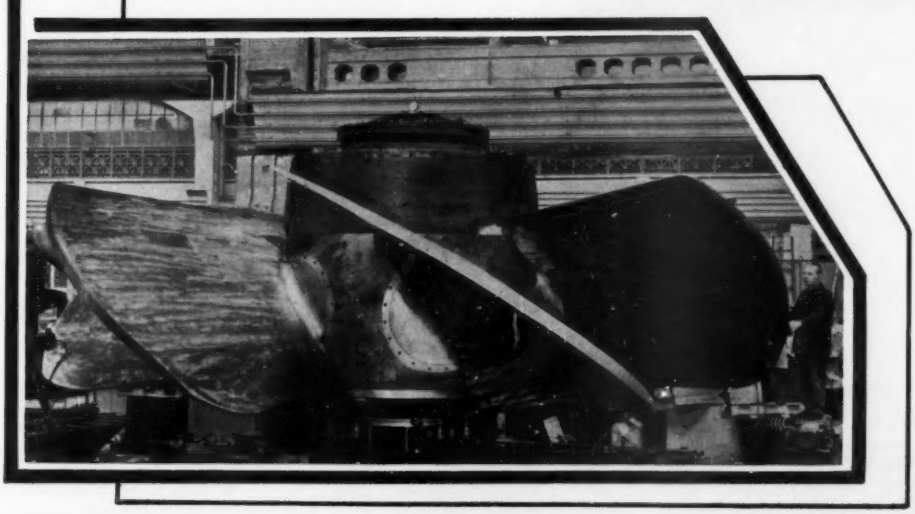


Assembly at works of an 11.150 kW Francis turbine for Pilmalquen Power Station of Mesyrs Endesa, Santjago (Chile)

Wheel of a 35.200 kW Pelton turbine for Lanzada Power station of Soc. Vizzola - Milan.

Wheel of a 35.750 kW Kaplan turbine for Ybbs Persenberg Power station of Osterreichische Donaukraftwerke, Wien



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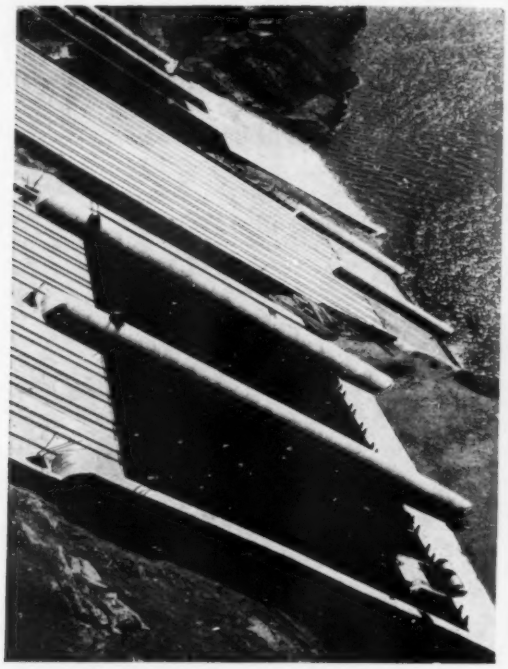

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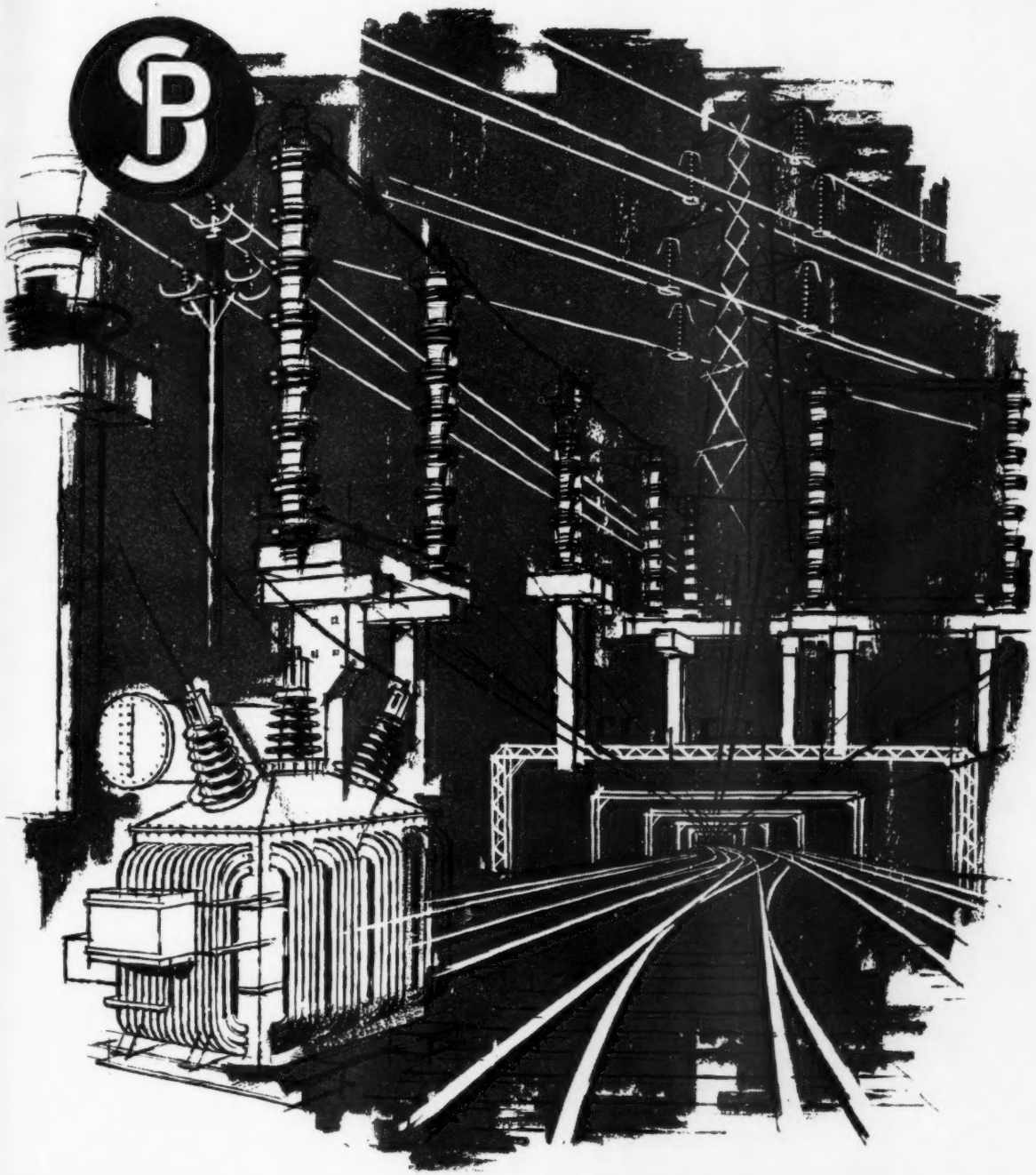

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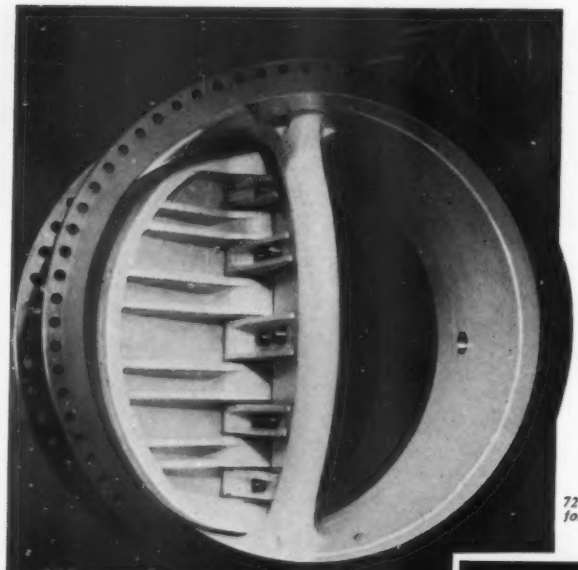

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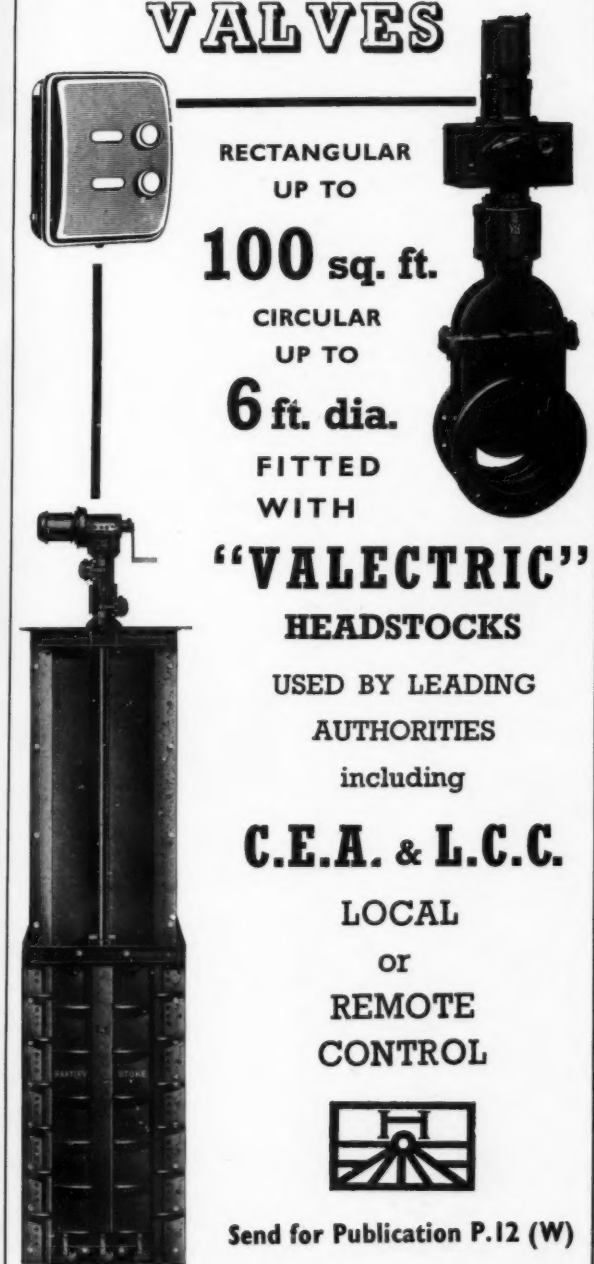

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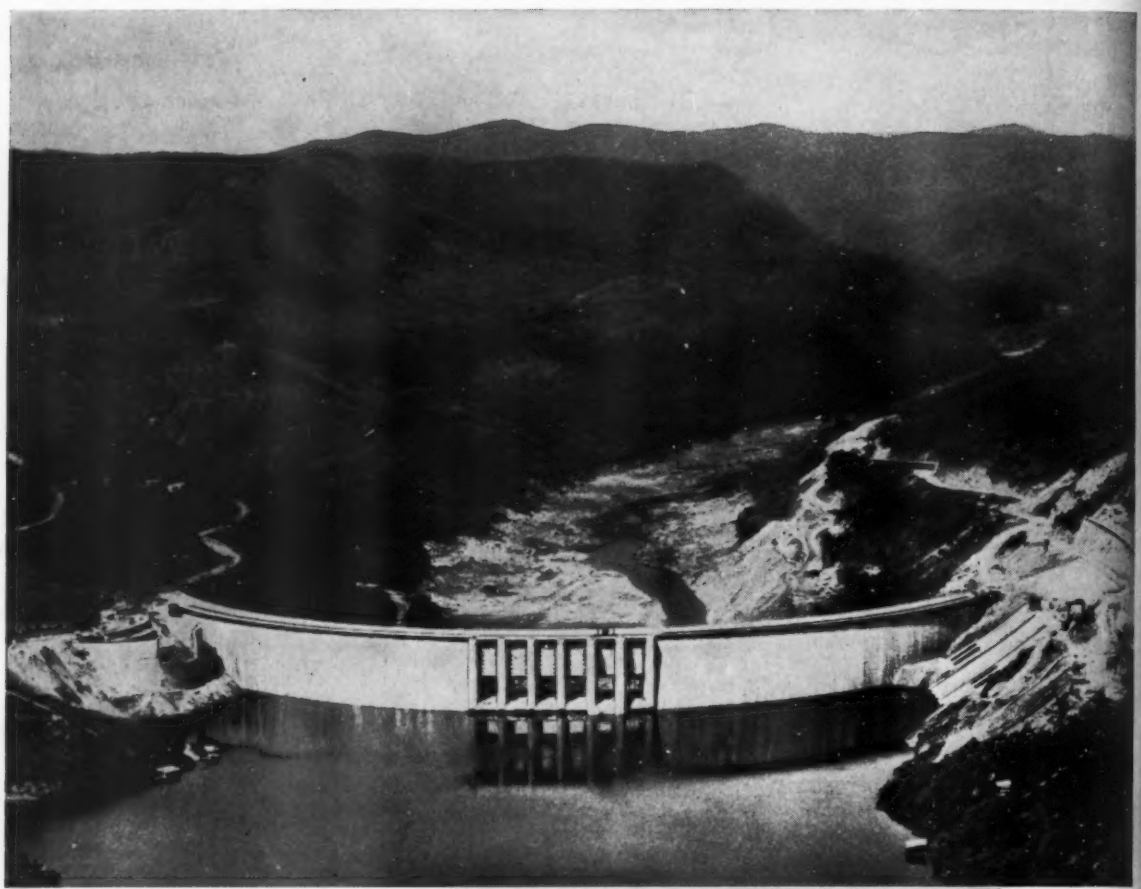

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